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Geographic Variation in Potential of Residential Solar Hot Water System Performance in the United States

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Abstract

This paper describes an assessment of residential solar water heater performance around the continental United States. We performed annual simulations using an hourly simulation model (*EGUSA*) for 212 TMY3 weather locations around the nation. The annual simulations show how standard hot water energy use for electric and gas systems vary geographically (kWh and therms) as well as the potential energy savings from solar water heaters. A key finding is that the energy necessary for water heating varies by 2:1 around the U.S. with implications for solar water heating system design and sizing. Our results provide information on expected water heater performance, solar systems savings and best configurations.

Keywords: solar water heaters, energy savings, simulations, *EnergyGauge USA, TRNSYS, BEopt*.

Executive Summary

Water heating accounts for a significant portion of the total annual energy consumption in a typical home in the United States. This paper describes a geographical assessment of residential solar hot water performance around the U.S. as a way of quantifying potential benefits and renewable energy contributions around the country.

Using a detailed hourly energy simulation software *EnergyGauge USA* (*EGUSA*), we simulated annual hot water energy use under the ASHRAE hot water draw profile. The analysis was conducted for 212 TMY3 (Typical Meteorological Year version 3) weather sites on a two-story three bedroom home. A total of eight different water heating systems were evaluated, giving clear indication on how hot water production varies throughout the U. S. For each TMY3 location we simulated both natural gas and electric water heaters as the standard storage systems. Each of these standard systems was then simulated with a 32 ft^2 integrated collector storage (ICS) solar water heating system, a 40 ft^2 and 64 ft^2 closed loop flat plate system respectively, for a total of eight systems (four with gas and four electric).

Flat plate systems showed the highest level of savings; a 40 ft^2 system with freeze protection showed the ability to meet 50 – 80% of energy requirements for water heating around most of the country (Figure E.1). The specific energy savings in *EGUSA* for the electric 40 ft^2 system averaged 2132 kWh for a solar fraction of 58 % (varying from 1473 – 3051 kWh and 35 – 64%). For the 40 ft^2 solar system with natural gas energy savings averaged 81.6 therms for a solar fraction of 40 % (varying from 54 – 113 therms and 24 – 43 %).

For a larger electric 64 ft^2 system of the same type, energy savings averaged 2621 kWh for a solar fraction of 71 % (varying from 2002 – 3875 kWh and 48 – 81 %). In the natural gas case, energy savings averaged 107.3 therms for a solar fraction of 53 % (varying from 78 – 154 therms and 34 – 59 %).

Solar fractions and savings were lowest for ICS systems numbers. The specific energy savings in *EGUSA* for the electric 32 ft^2 system averaged 1424 kWh for a solar fraction of 40 % (varying from 989 – 2001 kWh and 20 – 55 %). For the 32 ft^2 solar system with natural gas energy savings averaged 49.9 therms for a solar fraction of 25 (varying from 34 – 71 therms and 12 – 42%).

As a check on results we simulated annual hot water energy use for the same locations and configurations using the *TRNSYS* energy simulation software as implemented in *BEopt.* For the majority of the country, the discrepancies between both simulation programs are less than $\pm$10 % for a standard 40 gallons electric water heater combined with a 40ft^2 flat plate closed loop solar water heater (E40FPCL).

A key innovation in our analysis was that our annual simulations showed that standard energy requirements for water heating vary by more than 2:1 around the continental U. S because of varying inlet water temperatures. This has potential ramifications for both solar system performance, sizing and even optimal collector tilt—where greater energy loads in winter would suggest higher collector tilts than otherwise justified.[1] We present data both for absolute savings, and solar fraction. As it is shown in Figures E.1 and E.2, for E40FPCL, the annual simulations show how potential absolute and fractional energy savings from solar water heaters vary geographically around the U. S. The most commonly invoked unit of merit, fractional savings tells the percentage of water heating energy provided with respect to the case of only having a regular water heater. In practical terms, and given a fixed energy price, absolute savings gives an indication of relative economics. In general, colder, sunnier climates showed most attractive savings. Our analysis gives designers and builders in a specific region an indication of expected water heater performance and best configurations. A more detailed analysis was done for the states of Florida and California given current levels of interest in solar water heating.

Figure E.1: Annual fractional energy savings (%) for a standard 40 gallons electric water heater combined with a 40ft^2 flat plate closed loop solar water heater

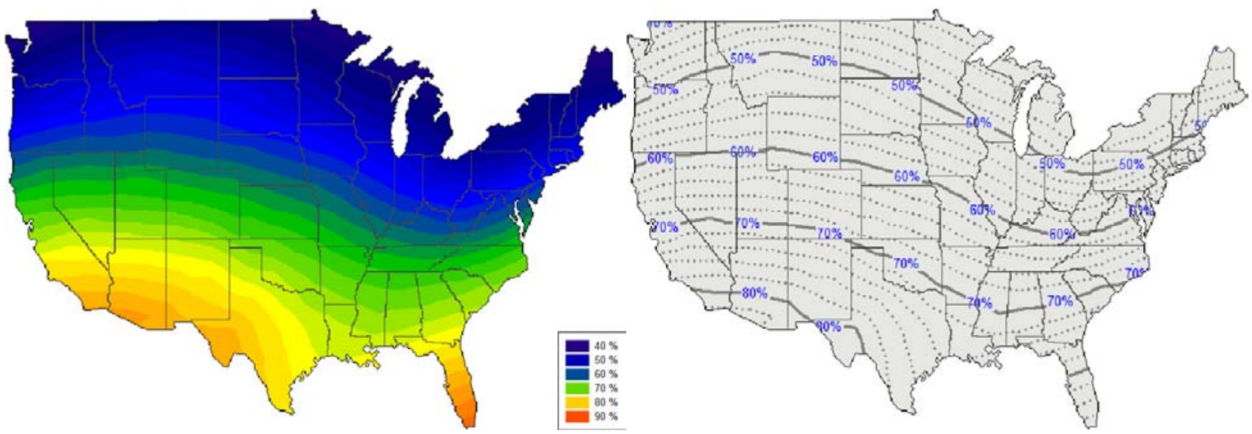
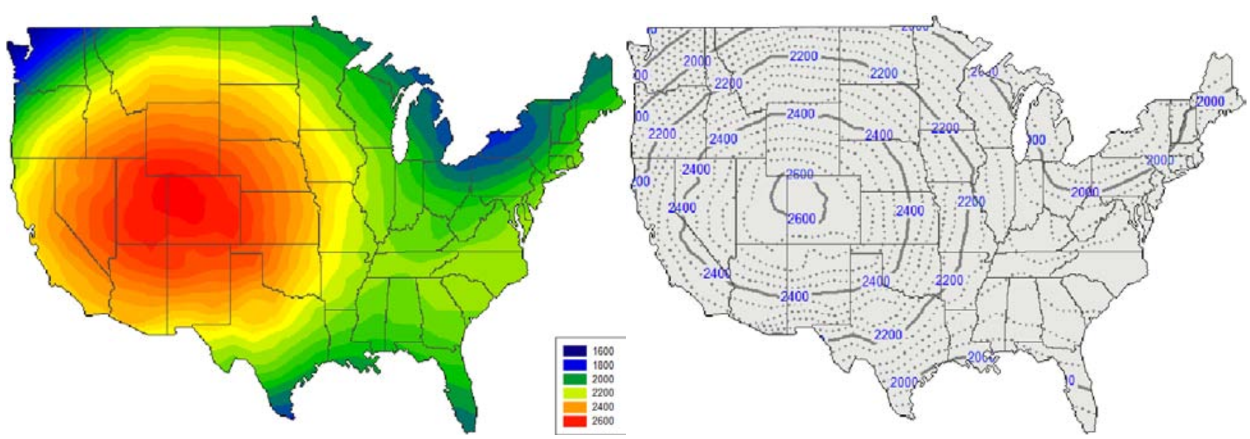


Figure E.2: Annual absolute energy savings in kWh for a standard 40 gallons electric water heater combined with a 40ft^2 flat plate closed loop solar water heater



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Introduction

Water heating accounts for a significant portion of the total annual energy consumption in a regular home. Solar domestic water heating is an alternative to help meet the hot water energy demands in a household. In order to visualize the potential benefits and contributions of solar systems, an assessment of residential roof-top solar hot water performance around the continental United States is developed through the document.

Using the energy simulation software *EnergyGauge USA* (*EGUSA*) [1] and *TRNSYS* [2] [3] as implemented in *BEopt* [6], we simulated annual hot water energy use in 212 TMY3 sites on a two-story three bedroom home for eight water heating systems, with the objective to learn how hot water system performance varies throughout the U. S. For each TMY3 location and software, we simulated both natural gas and electric water heaters as the standard storage systems. Each of these standard systems was then simulated with a 32 ft^2 integrated collector storage (ICS) solar water heating system, a 40 ft^2 and 64 ft^2 closed loop flat plate system respectively, for a total of eight systems (four with gas and four electric). Note that although concerns have been expressed in the past for the adequacy of simulations for ICS systems, *BEopt* uses *TRNSYS* for their simulation and *EGUSA* has been shown to very successfully emulate this software in its own calculation of ICS performance [6].

Solar Hot Water Systems

We choose the three solar water heating system as ones which are roughly representative of a large number of solar water heating installations being installed in the U.S. The integrated collector storage system reflects a popular batch type water heater with a series of water filled tubes filled with 40 gallons of water in an insulated structure under loss-heat loss glazing. These systems are popular in non freezing climates since the have no pumps, valves or moving parts and are considered very reliable. However, within the *EGUSA* simulation model, we assume the ICS systems were not available in any hour in which the temperature over the preceding day fell below freezing. No such limit is used within the *BEopt* program.

A second configuration is perhaps the most popular solar water heating system in the U.S. This consists of a single glazed 4 x 10' flat plate collector with high transmittance low iron glass connected by insulated piping to an 80 gallon storage tank. A glycol loop is utilized to provide freeze protection and an integral heat exchanger in the storage tank. The glycol loop is pumped by a small variable speed DC pump and is PV driven. A similarly performing system would consist of a drainback collector, although typically a larger AC pump would be required for this application. These systems are among the most successful of all solar water heating systems in the field across climates [7].

The third solar system is similar to the 4 x 10' collector system save that two 4 x 8' collectors are used in tandem. This provides a larger heat collection area along with a 80 gallon tank. With electric resistance water heating as the auxiliary, 4500 Watt elements in the solar storage tanks provide back up heat in case the solar system cannot meet the load. For natural gas systems, however, we assume that a two tank system with the auxiliary tank elevated to provide circulation from the solar tank via natural buoyancy.

Building Simulation Analysis

The simulations were performed on an hourly time step with results compiled on an annual basis (8,760 hours). Typical Meteorological Year Data (TMY3s) were used for all locations. A specific implementation of the software, *EGUSA* was used for the analysis. The analytical method used to predict hourly solar contributions in *EGUSA* is based on an hourly correlation of the *TRNSYS* simulation such that it could be implemented as a function within the DOE-2.E [6]. Further, we also used *TRNSYS* itself within the *BEopt* simulation to evaluate the performance of each electric solar system.

Description of the Simulated Home

Tables 1, 2 and 3 summarize the key specifications for the home used for our analysis.[2]

Table 1. Site and Envelope Key Specifications

Type:	2 stories, 3 bedrooms, 2 bathrooms, 1800 ft^2
Occupancy:	Single Family
Draw profile:	ASHRAE [7] [8] [9]
Shading:	No shade trees, no adjacent buildings
Weather Data:	Typical Meteorological Year version 3 (TMY3)
Attached Garage:	Yes
Roof area:	1007 ft^2
Roof slope:	6/12 inches

Table 2. Standard Hot Water Systems Specifications

Type:	Natural Gas	Electric
Efficiency:	0.59	0.9
Location:	Garage	Garage
Capacity:	40 gallons	40 gallons
Daily Use:	60 gallons	60 gallons
Set Temperature:	120 °F	120 °F

[2] Note that we assume a standard 6/12 roof pitch with a resulting 27 degree slope. Given the practical desirability from homeowners of good aesthetic appearance with flush-mounted collectors, this tilt was utilized in all locations.

Table 3. Solar Hot Water Systems Specifications

Integrated Collector Storage (ICS)	
Cover area:	30.1 ft^2
Tilt:	27 °
Azimuth:	180 °
Tank loss coefficient:	17.06 Btu / hr · ° F
Transmittance absorptance product:	0.82
Volumetric capacity:	41.2 gallons

Table 3. Solar Hot Water Systems Specifications (continuation)

Flat plate (closed loop)		
Surface area:	40 ft^2	64.1 ft^2
Tilt:	27 °	27 °
Azimuth:	180 °	180 °
Loss coefficient:	0.734 Btu/ hr · ft^2 · ° F	0.734 Btu/ hr · ft^2 · ° F
Transmittance absorptance product:	0.78	0.78
Storage tank volume:	80 gallons	80 gallons
Transmittance correction:	0.96	0.96
Storage tank U-value:	0.123 Btu/ hr · ft^2 · ° F	0.123 Btu/ hr · ft^2 · ° F
Storage tank surface area:	25 ft^2	25 ft^2
Heat exchanger correction factor:	0.88	0.88

Weather Data

Hourly weather data used for the simulation was obtained from the *Typical Meteorological Year* version 3 (TMY3) derived from the 1976-2005 *National Solar Radiation Data Base* (NSRDB). TMY3 is a data set of hourly values of solar radiation and meteorological elements for a one-year period. It consists of months statistically selected from individual years and concatenated to form a complete year. The intended use is for computer simulations of solar energy conversion systems and building systems [10].

Modeling Mains Water Temperature

The inlet water temperature of a water heating system is a primary determinant of the energy requirement to bring the final delivery temperature to 120 °F. Commonly in the past, the mains water temperature has been assumed to be nearly fixed at the average well temperatures in a location. However, recently collated data from around the U.S. shows that water supply temperatures have a strong seasonal component since mains are not deeply buried. This seasonal variation has important implications for water heating systems—particularly for solar water heating systems where available insolation also varies such that lowest levels are available in winter.[3] To address this important need, Hendron et al. [11] have summarized various data sources and produced a calculation method to estimate mains water temperature depending on location, weather data and time of year (Equation 1):

$$T_{mains} = (T_{amb,\,avg} + \text{offset}) + \text{ratio} \cdot \left(\frac{\Delta T_{amb,\,max}}{2}\right) \cdot \sin\big(0.986 \cdot (\text{day\#} - 15 - \text{lag}) - 90\big) \qquad (1)$$

where: T_{mains} = mains (supply) temperature to domestic hot water tank (°F)

$T_{amb,avg}$ = annual average ambient air temperature (°F)

$\Delta T_{amb,\,max}$ = maximum difference between monthly average ambient temperatures (e.g., $T_{amb,avg,july} - T_{amb,\,avg,\,january}$) (°F)

0.986 = degrees / day (360 / 365)

day# = Julian day of the year (1 - 365)

offset = 6 °F

ratio = $0.4 + 0.01 \cdot (T_{amb,avg} - 44)$

lag = $35 - 1.0 \cdot (T_{amb,avg} - 44)$ (°F)

This equation is based on analysis by Craig Christensen and Jay Burch of the National Renewable Energy Laboratory (NREL) using data for multiple locations compiled by Abrams and Shedd [12], the Florida Solar Energy Center, Sandia National Laboratories, and others. When using this equation, a lower limit of 32 °F should be enforced for T_{mains} regardless of the local weather conditions. The offset, ratio and lag factors were determined by fitting a sinusoidal curve to the available data. The climate-specific ratio and lag factors reflect the practice of burying water pipes deeper in colder climates.

For models that use average monthly mains temperature, Equation 2 is used to calculate day#.

$$\text{day\#} = 30 \cdot \text{month\#} - 15 \qquad (2)$$

An example using Equation 2 to determine the monthly mains temperature profile for Chicago, Illinois, is shown in Figure 1. Average daily hot water usage (labeled DHW gal / day) was calculated using the equations in Table 4 based on cold water supplied at the mains temperature and hot water supplied at 120 °F.

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[3] We acknowledge that a changing mains water temperature will also likely lead to some change in hot water seasonal demand (e.g. see one study which showed a 27% seasonal change in hot water volume used by season in Florida: T. Merrigan and D. Parker, 1990 "Electrical Use, Efficiency, and Peak Demand of Electric Resistance, Heat Pump, Desuperheater, and Solar Hot Water Systems," Proceedings of the 1990 ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, August 1990, Pacific Grove, CA) However, without evaluation of how this change in demand would vary around the U.S. we conducted this analysis assuming that the volume of water used would remain constant year round).

Figure 1. Mains temperature profile for Chicago

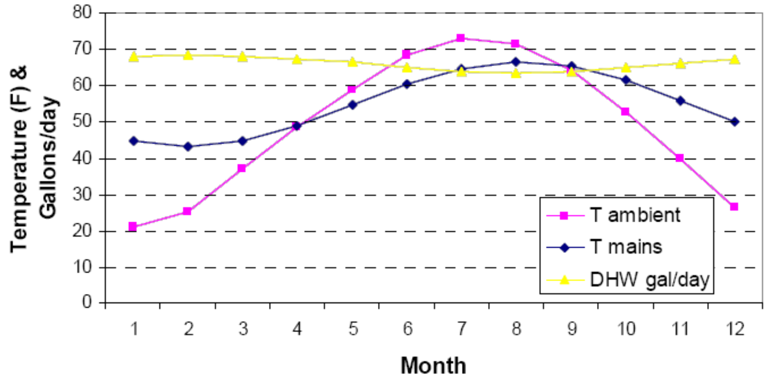


Table 4. Domestic hot water consumption by end-use

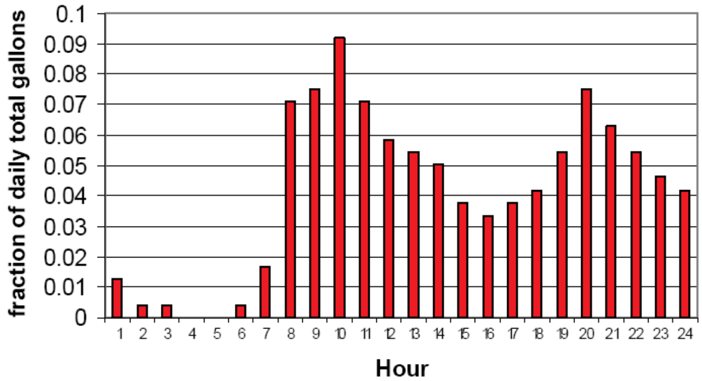
End-Use	End-Use Water Temperature	Water Usage
Clothes Washer	N/A	$7.5 + 2.5 \cdot N_{br}$[1] gal / day (Hot Only)
Dish-washer	N/A	$2.5 + 0.833 \cdot N_{br}$ gal / day (Hot Only)
Shower and Bath	105 °F	$14 + 4.67 \cdot N_{br}$ gal / day (Hot + Cold)
Sinks	105 °F	$10 + 3.33 \cdot N_{br}$ gal / day (Hot + Cold)

[1] N_{br} = number of bedrooms

Simulation Results

We evaluated the data from the simulations in all TMY3s locations summarizing by city and state. Appendix C shows the *EGUSA* simulated annual energy requirements for the standard systems (electric and gas), and savings for the remaining three water heaters in each case with respect to their respective standard system. In this simulation the ASHRAE draw profile distributed according to Figure 2 [7] [8] [9] is assumed. A daily hot water consumption of 60 gallons per day was assumed in *EGUSA*, however the specific consumption for shower and sink use in *BEopt* varies slightly with climate as shown in Table 4. Nevertheless, daily hot water consumption in *BEopt* is only slightly different from 60 gallons per day— although typically somewhat less. Appendix D shows a table with the *BEopt* simulated annual energy requirements for the standard systems (electric and gas), and savings for the remaining six water heaters with respect to their respective standard system.

Figure 2. Hot water use profile [7]



The eight systems simulated are:

E:	Standard electric resistance storage tank
E32ICS:	Standard electric with a 32 ft^2 integrated collector storage (ICS) system
E40FPCL:	Standard electric with a 40 ft^2flat plate closed loop system
E64FPCL:	Standard electric with a 64 ft^2flat plate closed loop system
G:	Standard natural gas storage tank
G32ICS:	Standard natural gas with a 32 ft^2 integrated collector storage (ICS) system
G40FPCL:	Standard natural gas with a 40 ft^2flat plate closed loop system
G64FPCL:	Standard natural gas with a 64 ft^2flat plate closed loop system

Annual absolute and fractional savings are listed to show how much the solar systems contribute in offsetting energy loads for each site. Absolute savings (AS) are shown in kWh or in therms depending on the system and fractional savings (FS) are shown in percentage (%).

The *EGUSA* simulated systems produced 17 % to 95 % of the water heating needs around the continental U. S. for the electric case and 11 % to 77 % for the natural gas case.

Geographic variation of energy requirements for standard water heaters

Using data from the annual simulations we created contour plot graphic representations of the *EGUSA* estimated energy requirements for standard storage water heaters throughout the continental U. S. The resulting *EGUSA* performance contours are shown in Figures 3 and 4. Note that the energy consumption varies from 2,200 – 4,800 kWh for the electric resistance system and from 120 – 260 therms for the gas system around the U. S., a variation of more than 2:1. Lower energy requirements are found in the southern states with warmer inlet mains water temperatures. The highest energy requirements are seen tending towards the extreme North portion of the country where cold ground temperatures prevail. *BEopt* performance contours of the estimated energy requirements for the standard storage electric system are shown in Appendix E.

Figure 3. Annual energy consumption in kWh for a standard storage electric water heater

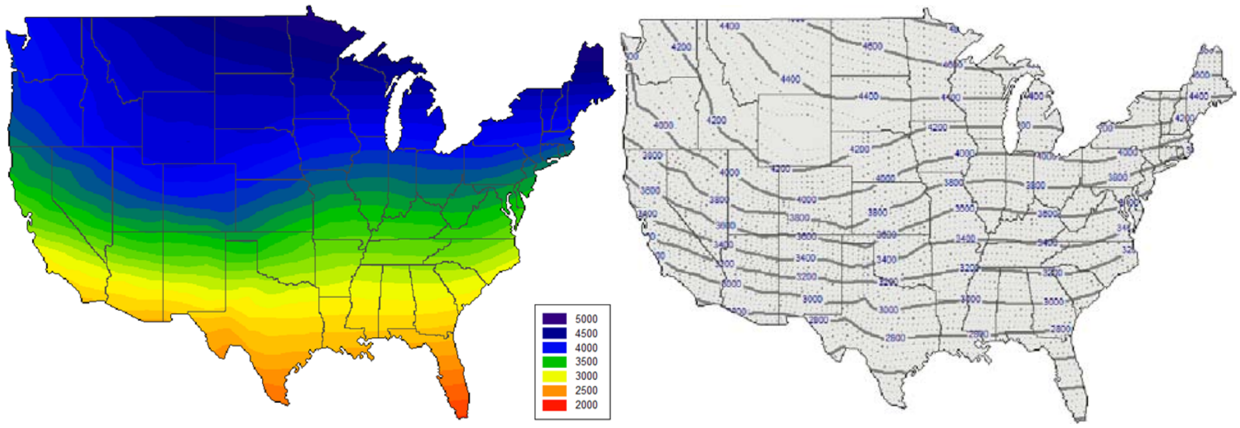
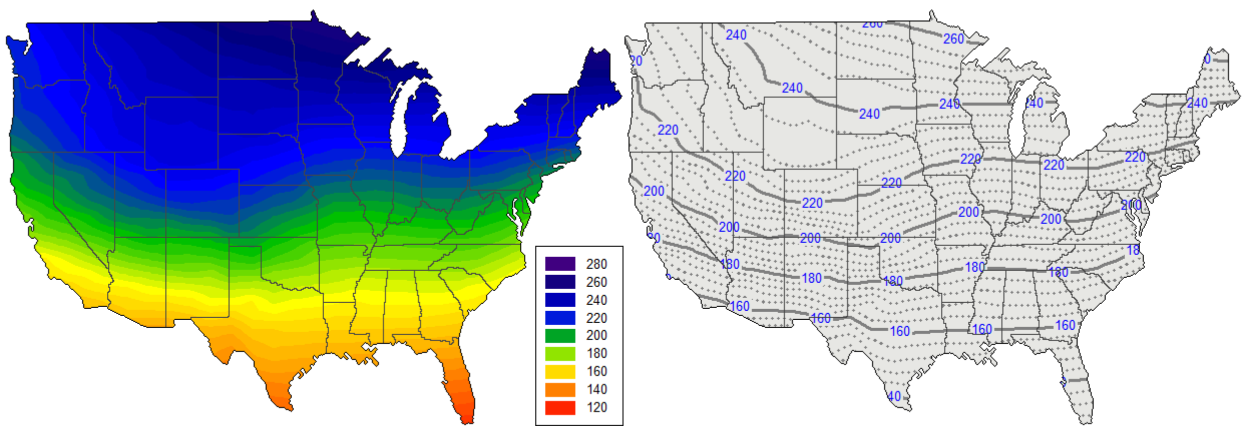


Figure 4. Annual energy consumption in therms for a standard storage gas water heater



Geographic variation of absolute and fractional energy savings for solar water heaters

As before, we created contour plot graphic representations of the *EGUSA* estimated absolute and fractional energy savings for different combinations of standard storage water heaters with solar systems throughout the continental U. S. The resulting performance contours for E32ICS and E64FPCL are shown in Figures 5 through 8. The remaining electric and natural gas plots can be seen in appendices A and B respectively. Note that the energy savings varies from 1,000 – 3,200 kWh (20 - 78%) around the U.S. Lowest savings are from the ICS systems and the highest savings came from the larger close loop flat plate system. For the solar gas systems, energy savings varies from 35 – 130 therms (13 - 58 %) starting with G32ICS and ending with G64FPCL (see appendix B). Savings for solar systems with a 2-tank natural gas system are lower because of center flue and plumbing losses. Although, not simulated, much better results can be obtained with solar systems mated with a tankless gas water heater auxiliary system.

Figure 5. Annual absolute energy savings in kWh for E32ICS

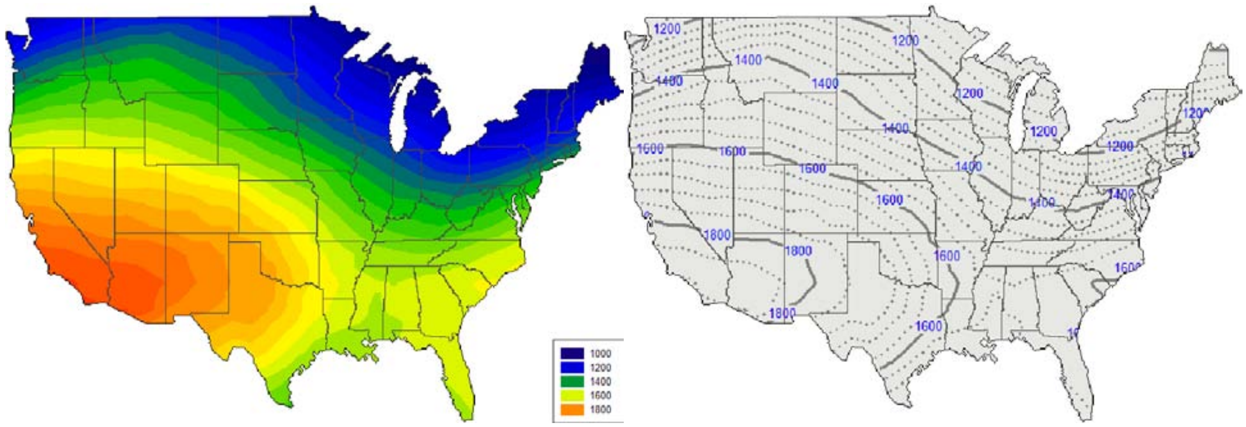


Figure 6. Annual fractional energy savings (%) for E32ICS

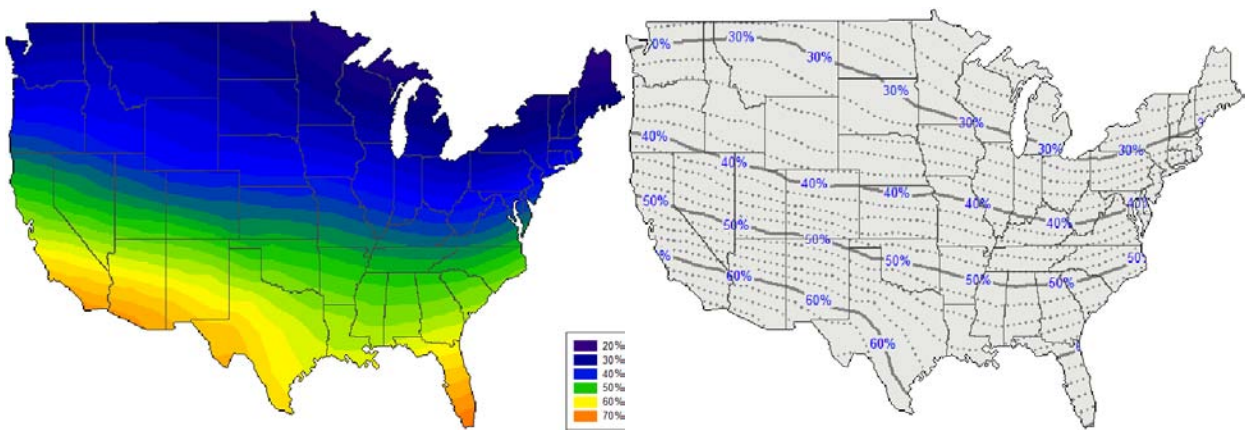


Figure 7. Annual absolute energy savings in kWh for E64FPCL

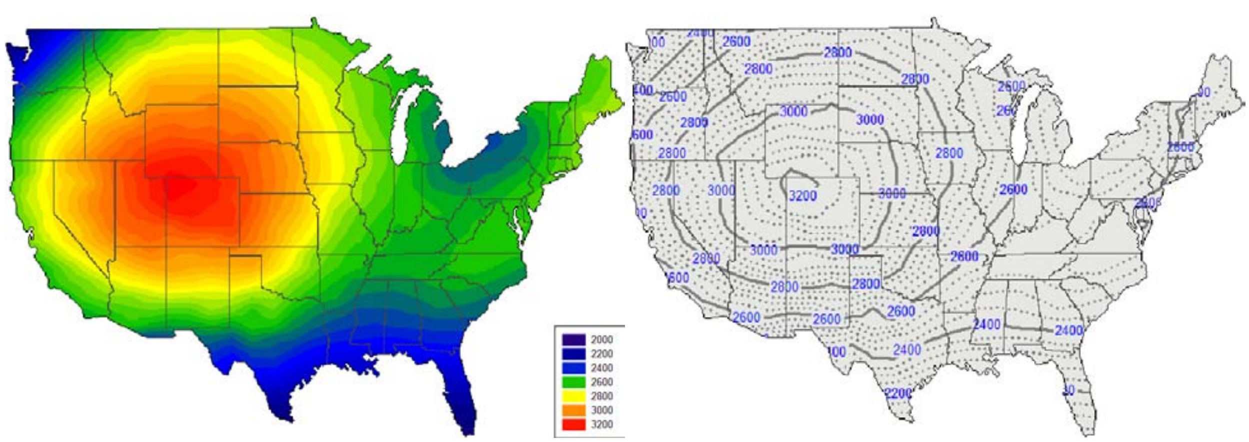
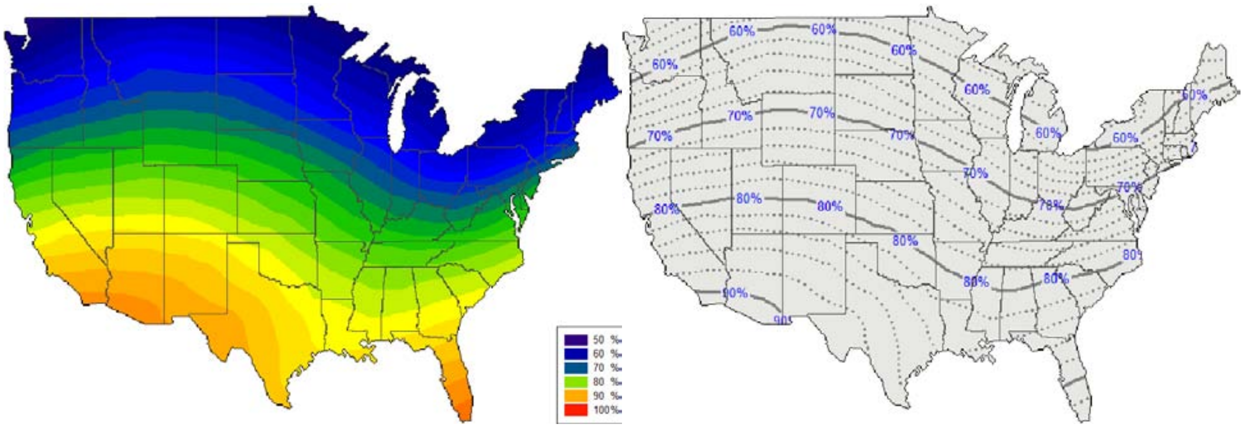


Figure 8. Annual fractional energy savings (%) for E64FPCL



Absolute Solar Savings vs. Solar Fraction

Typically, the savings of solar systems are evaluated by the fraction of the overall water heating load that is served by the solar system element versus the system auxiliary heating system. "Solar fraction" was further popularized by the analytical F-chart method developed by Duffie and Beckman [13] and is commonly used to describe solar system performance.

While this method is correct from an analytical standpoint, we show in our analysis that when evaluating performance of similar solar water heating systems around the U.S., the absolute energy savings in terms of kWh and therms represents a better indicator of the economic attractiveness of solar systems given a fixed energy price. This arises because the water heating load itself varies with geographic location in the United States. Generally, the colder regions of the country have the greater water heating loads due to lower ground and well water temperatures as well as piping losses in garages, basements and semi-conditioned utility rooms where tanks are commonly located. The end result, as shown later in our series of plots showing the absolute savings of solar water heating systems, is that the absolute energy savings of solar water heating systems is greatest in the colder, sunnier locations. Not surprisingly, as shown in Figures 9 and 10 for a 40 ft^2 closed loop system (perhaps the most popular system type), the greatest absolute savings are seen in cold and clear southern Rocky Mountain area in northern New Mexico, Colorado and Utah (compare to fractional savings in Figures 11 and 12 respectively). However, our analysis clearly shows that significant energy savings are available around the United States—particularly for flat plate systems which often produce 50 - 80% of necessary water heating energy.

Figure 9. Annual absolute energy savings in kWh for E40FPCL

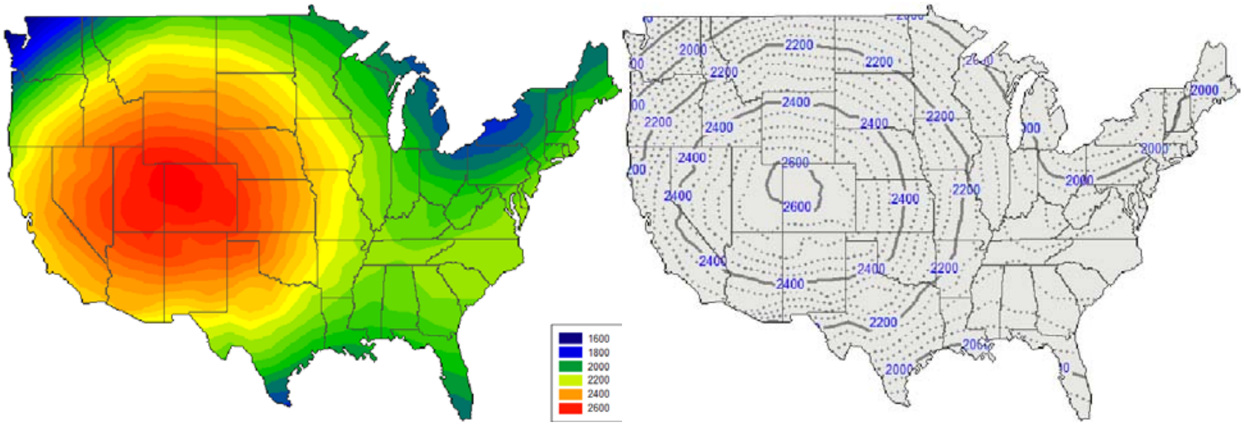


Figure 10. Annual absolute energy savings in therms for G40FPCL

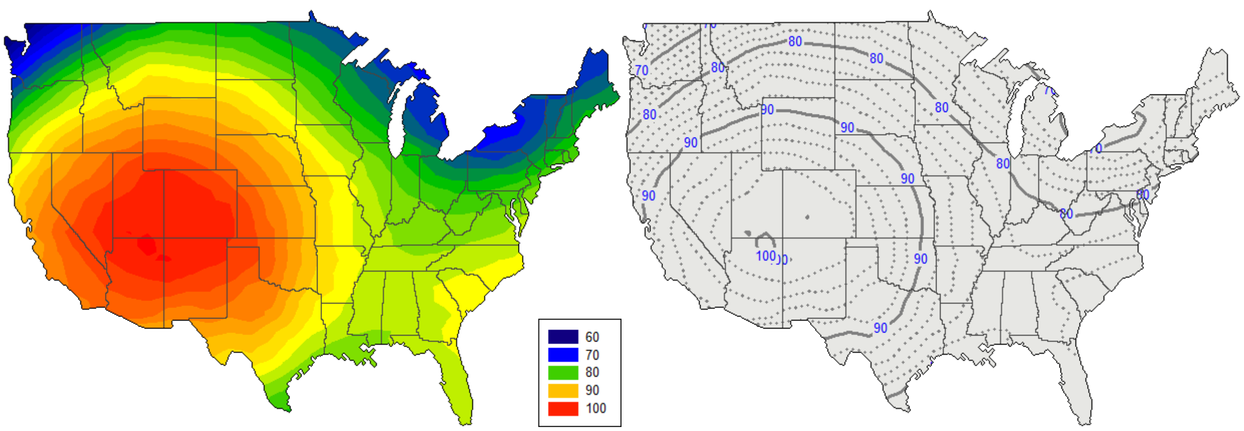


Figure 11. Annual fractional energy savings (%) for E40FPCL

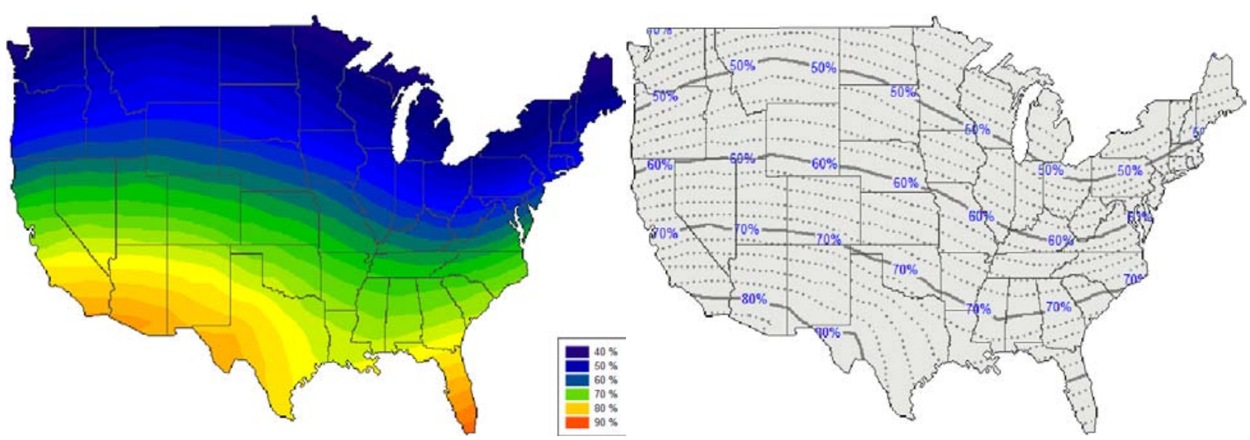
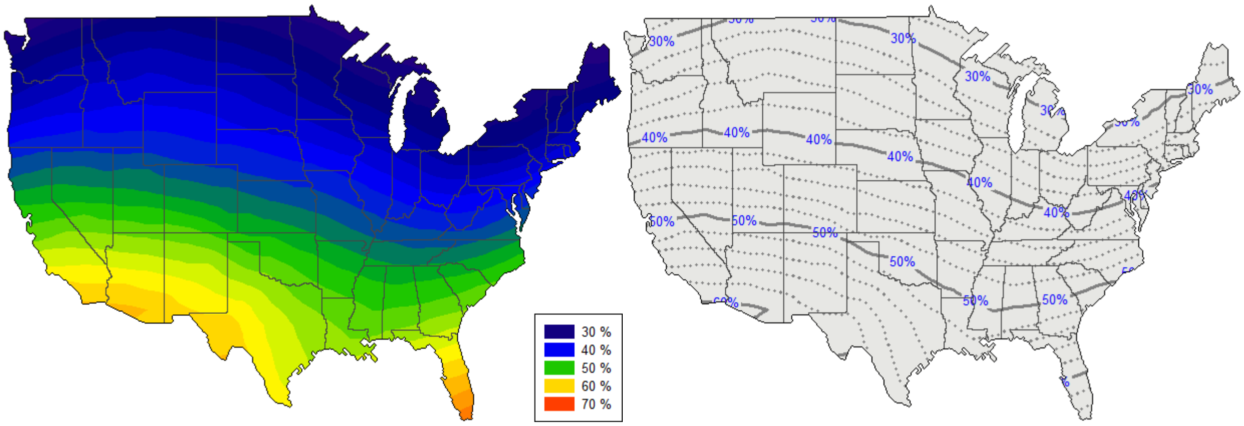


Figure 12. Annual fractional energy savings (%) for G40FPCL



In practical terms, absolute savings gives you an indication of the amount of money (energy) that would be saved, while solar fraction indicates the percentage of annual water heating needs that are met. The greatest fractional savings are seen in the state of Florida, while the largest absolute savings are seen in Colorado and locations nearby.

Although not done here, if the results were further modified by prevailing energy prices, one would find that systems look exceedingly attractive in the Northeastern U.S. and in California where higher energy prices tend to prevail.

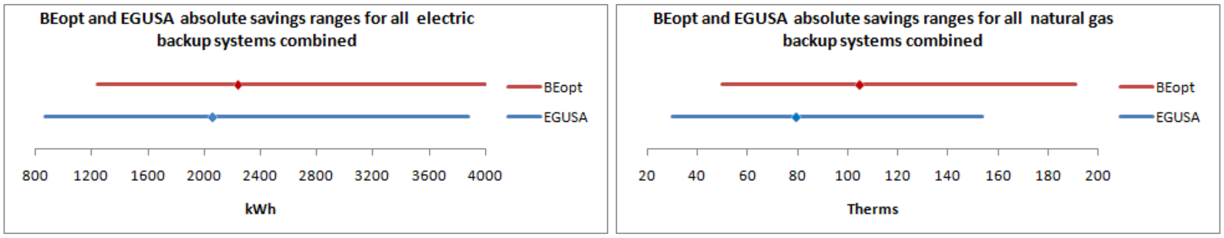
Comparison between *EGUSA* and *BEopt* simulations

Comparing the same locations for both programs, we found the following results. The *EGUSA* simulated systems produced energy savings from 989 – 3,875 kWh (20 % – 81%) starting with E32ICS and ending with E64FPCL for the solar electric systems. For the solar gas systems, energy savings varies from 34 – 154 therms (12 % - 59 %) starting with G32ICS and ending with G64FPCL.

The *BEopt* simulated systems produced energy savings from 1,239 – 3,997 kWh (30 % – 86%) starting with E32ICS and ending with E64FPCL for the solar electric systems. For the solar gas systems, energy savings varies from 50 – 191 therms (23% – 80 %) starting with G32ICS and ending with G64FPCL.

A graphic comparison of the above quantities can be seen in Figure 13 where the averages shown are 2059 and 2242 kWh for the electric case and 80and 105 therms for the natural gas case.

Figure 13. *BEopt* and *EGUSA* ranges comparison for electric and gas systems



In general, *BEopt* simulation results present more optimistic predictions, especially for natural gas systems. Figures 14 and 15 show detailed absolute savings ranges for each system. Here, we can see that for electric and natural gas systems *BEopt* still shows more optimistic predictions than *EGUSA* for all cases. For the electric systems, similar predictions are seen for flat plate closed loop systems and the bigger discrepancies are seen for the ICS system. The difference in the prediction for ICS systems is expected since *EGUSA* assumes these systems do not operate on days where the temperature is below freezing whereas *BEopt* does not assume this limitation. For the natural gas systems the variations in the prediction ranges are considerably bigger than the variations for the electric systems. This is not surprising since *EGUSA* assumes a two-tank system for natural gas leading to higher losses from the auxiliary tank center flue and associated piping. In the natural gas cases the biggest discrepancy is also seen in the ICS system (G32ICS). Table 6 shows the averages of the detailed absolute savings ranges for each system which are also indicated on Figures 14 and 15.

Figure 14. *BEopt* and *EGUSA* detailed comparison for electric systems

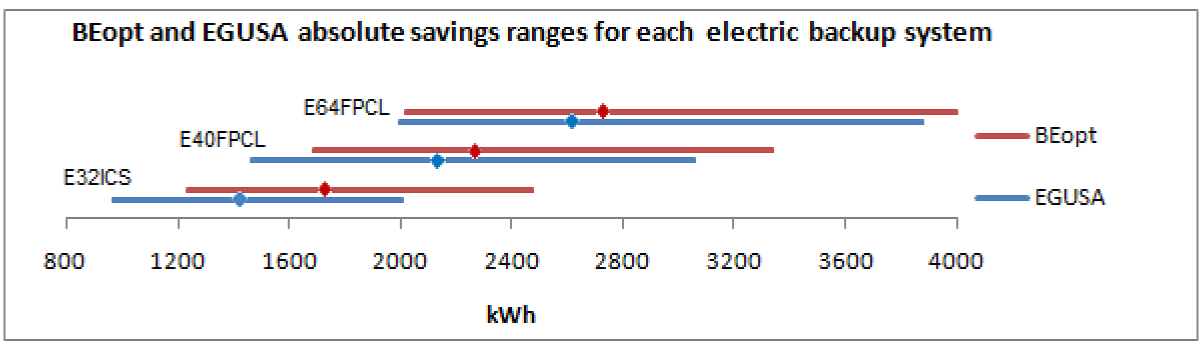


Figure 15. *BEopt* and *EGUSA* detailed comparison for natural gas systems

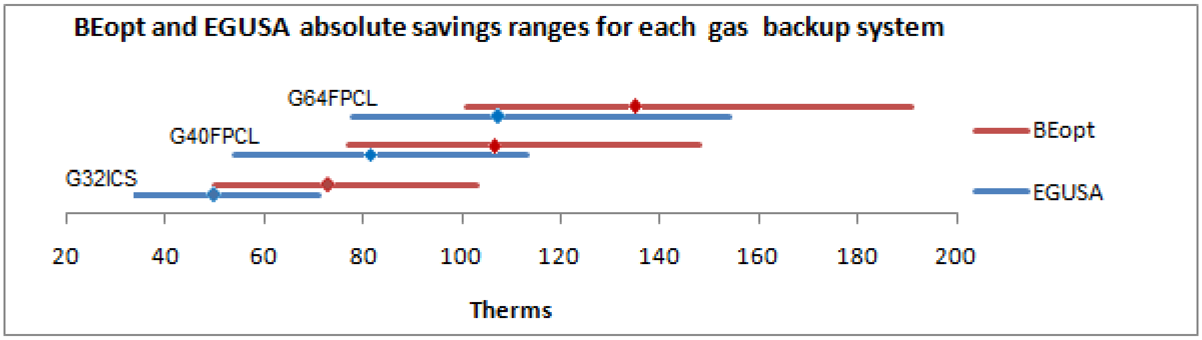


Table 6. Averages of the detailed absolute savings ranges for each system

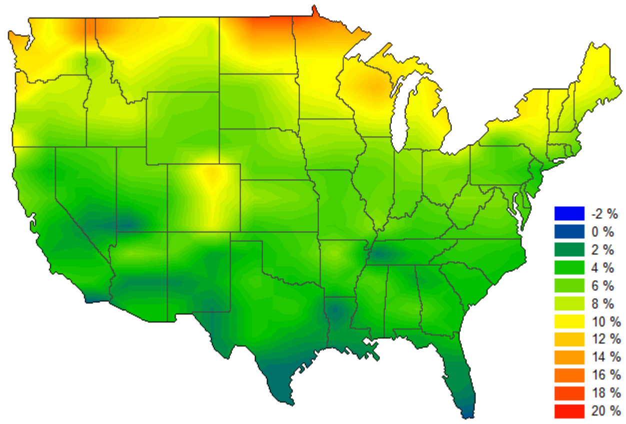
	E32ICS (kWh)	E40FPCL (kWh)	E64FPCL (kWh)	G32ICS (Therms)	G40FPCL (Therms)	G64FPCL (Therms)
BEopt	1728	2270	2728	72.8	106.7	135
EGUSA	1424	2132	2622	49.9	81.6	107.3

The differences in prediction of absolute energy savings in *BEopt* with respect to *EGUSA* on a city by city basis are shown in Appendix I for all systems. As we stated before, in general *BEopt* presents more optimistic results. Again, for the electric systems the biggest discrepancy is seen in E32ICS where *BEopt* shows absolute energy savings between 2% and 60% higher than the predictions in *EGUSA—an expected result given the differing assumptions of ICS availability in the EGUSA analsysi*. The closest results are seen in E64FPCL where *BEopt* shows absolute energy savings between - 4 % and 14 % with respect to *EGUSA*.

For the natural gas systems the biggest discrepancy is seen in G32ICS where *BEopt* shows absolute energy savings between 23% and 91% higher than the predictions in *EGUSA*. The closest results to *EGUSA* are seen in G64FPCL where *BEopt* shows absolute energy savings between 15% and 36% higher.

Figure 16 shows how the differences between *BEopt* and *EGUSA* are geographically distributed for E40FPCL around the continental United States. It can be seen that for most of the country, the discrepancies between both simulation programs are less than ±10 % for this type of system. Closed loop flat plate types are the most popular solar water heating systems in the U.S.

Figure 16. Geographically distributed differences of *BEopt* predictions vs. *EGUSA* for E40PFCL



Conclusions

We performed annual simulations for 212 TMY3 data locations throughout the continental United States on a two-story three bedroom two bathroom home with eight different water heaters under the ASHRAE draw profile. These annual simulations show how standard energy requirements for water heating vary by more than 2:1 around the continental U. S. Also potential energy savings from solar water heaters vary geographically around the U.S. Our analysis gives designers and builders in a specific region an indication of expected solar water heater savings. We presented data both for absolute savings, and solar fraction. Absolute savings are quite different from solar fraction since the variation in the magnitude of water heating loads alters the attractiveness of solar water heating.

Flat plate systems showed the highest level of savings; a 40 ft^2 system with freeze protection showed the ability to meet 50 – 80% of energy requirements for water heating around most of the country (Figure E.1). The specific energy savings in *EGUSA* for the electric 40 ft^2 system averaged 2132 kWh for a solar fraction of 58 % (varying from 1473 – 3051 kWh and 35 – 64%). For the 40 ft^2 solar system with natural gas energy savings averaged 81.6 therms for a solar fraction of 40 % (varying from 54 – 113 therms and 24 – 43 %).

For the flat plate closed loop electric 64 ft^2 system, energy savings averaged 2621 kWh for a solar fraction of 71 % (varying from 2002 – 3875 kWh and 48 – 81 %). In the natural gas case, energy savings averaged 107.3 therms for a solar fraction of 53 % (varying from 78 – 154 therms and 34 – 59 %).

Solar fractions and savings were lowest for ICS systems numbers. The specific energy savings in *EGUSA* for the electric 32 ft^2 system averaged 1424 kWh for a solar fraction of 40 % (varying from 989 – 2001 kWh and 20 – 55 %). For the 32 ft^2 solar system with natural gas energy savings averaged 49.9 therms for a solar fraction of 25 (varying from 34 – 71 therms and 12 – 42%).

Better results could be accomplished by customizing the efficiency components of the water heating system to fit a particular location. For instance, as expected, we found ICS systems to work best in mild climates. Moreover, for the natural gas, we also determined that solar works best with tankless gas auxiliary systems due to center flue and piping losses in two-tank systems. Future evaluations might consider the best water heater designs by climate including prevailing energy costs.

In our analysis we showed the absolute energy savings in terms of kWh and therms, best characterize the relative attractiveness of solar systems around the U.S. This arises since the water heating load itself strongly varies with climatic severity due to prevailing ground water temperatures. When this is considered, solar looks best in cold, clear areas such as Colorado when a fixed energy price is assumed.

In general, *BEopt* simulation results suggest more optimistic predictions than *EGUSA*, especially for natural gas systems where *EGUSA* likely makes more pessimistic assumption relative to the thermal losses for two tank systems. However, for the majority of the country, the discrepancies between both simulations are less than ±10 % in the E40FPCL case.

Acknowledgements

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Appendix A: *EGUSA* Auxiliary Electric Water Heaters Contour Plots

Figure A1. Annual energy consumption in kWh for a standard storage electric water heater

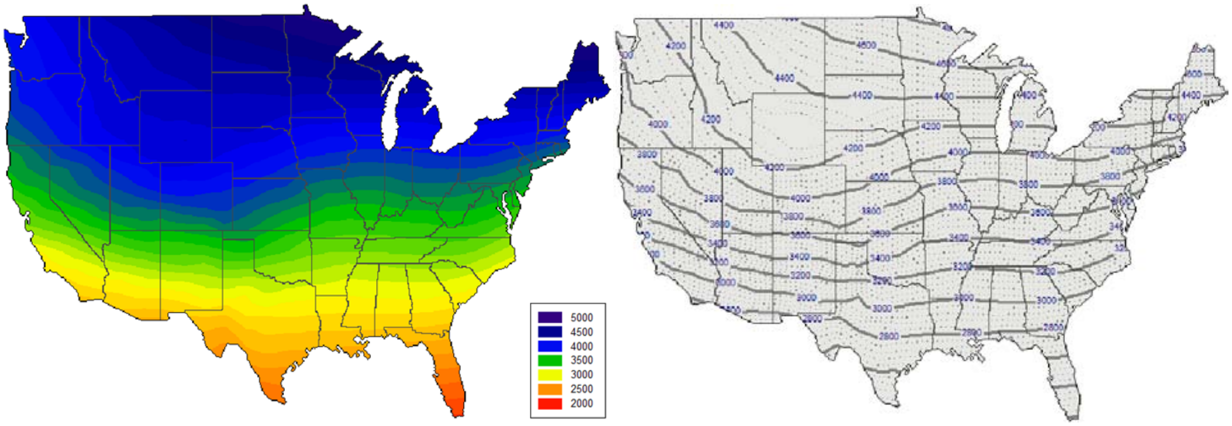


Figure A2. Annual absolute energy savings in kWh for E32ICS

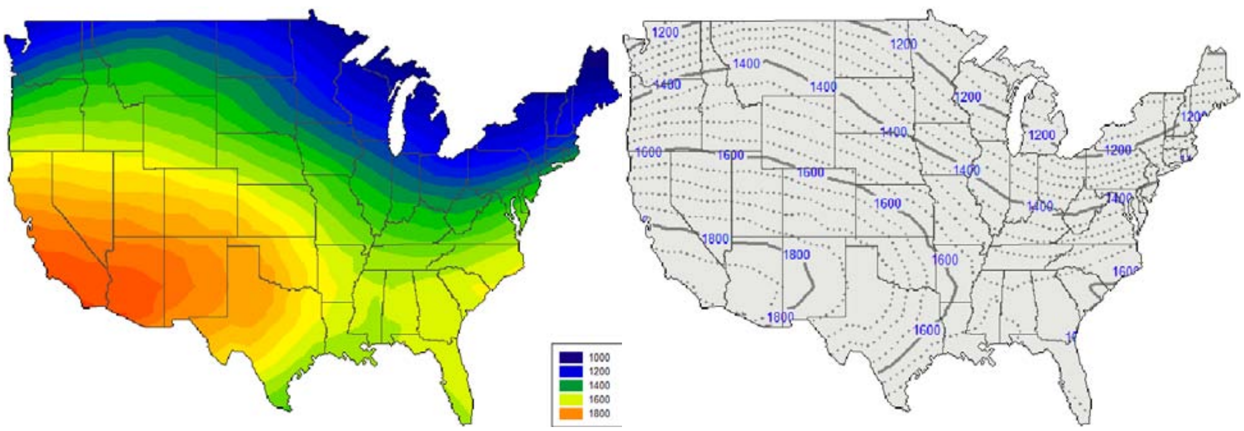


Figure A3. Annual fractional energy savings (%) for E32ICS

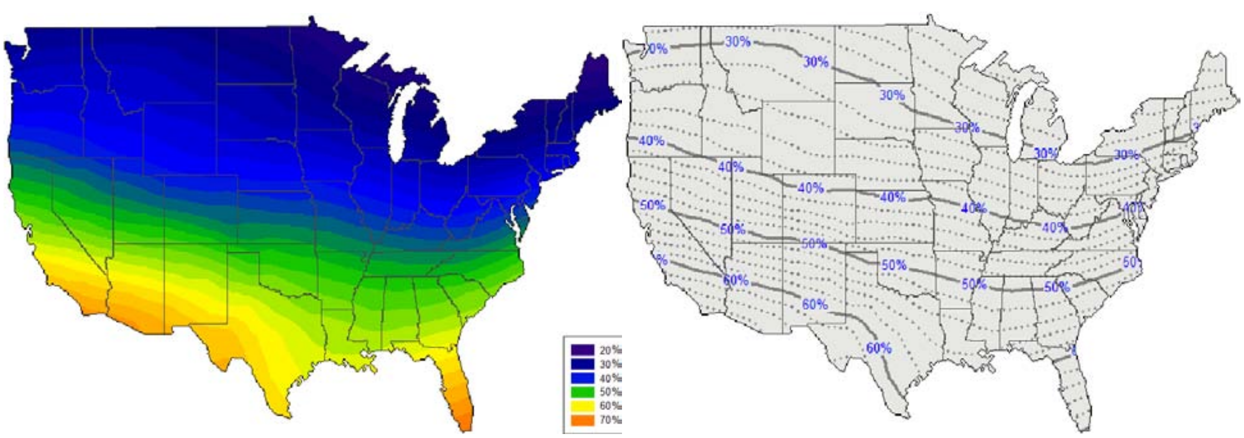


Figure A4. Annual absolute energy savings in kWh for E40FPCL

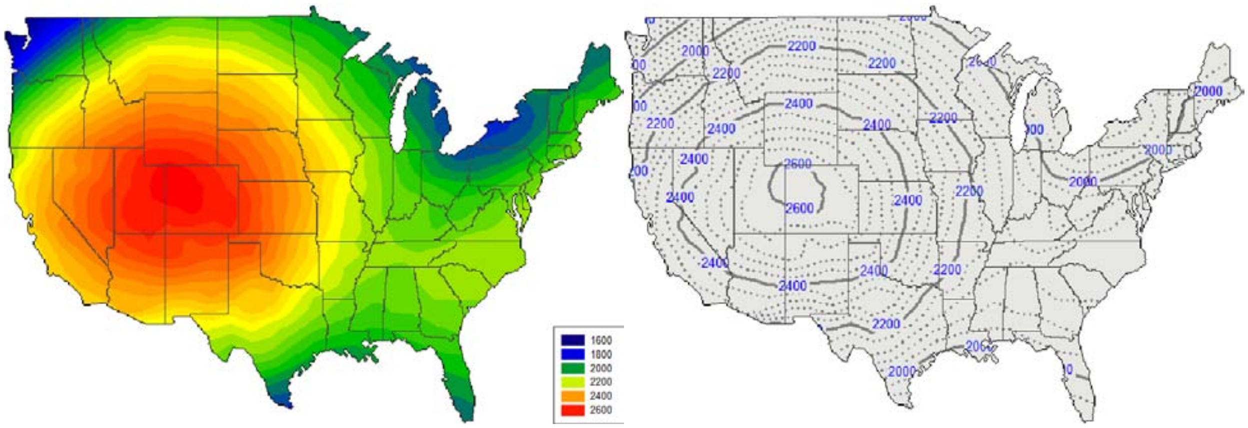


Figure A5. Annual fractional energy savings (%) for E40FPCL

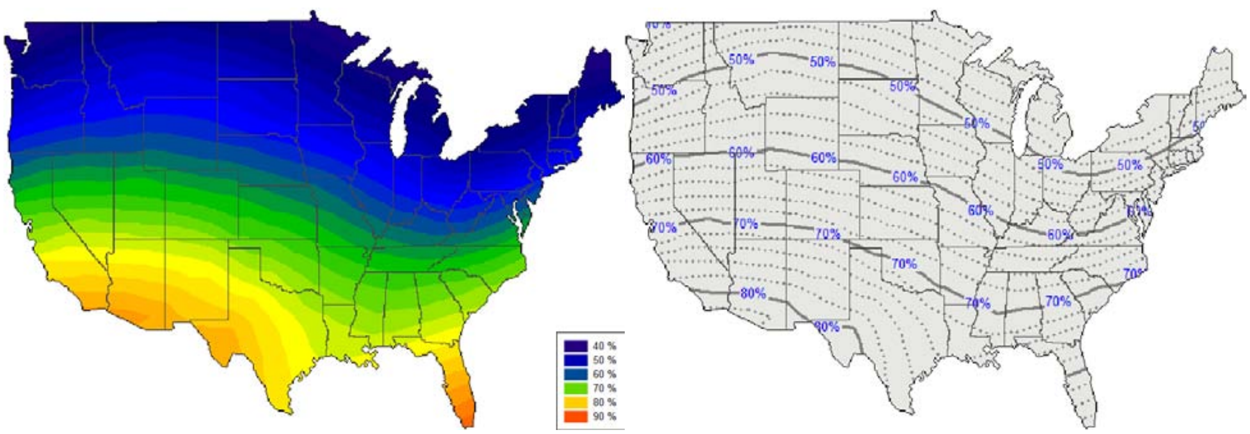


Figure A6. Annual absolute energy savings in kWh for E64FPCL

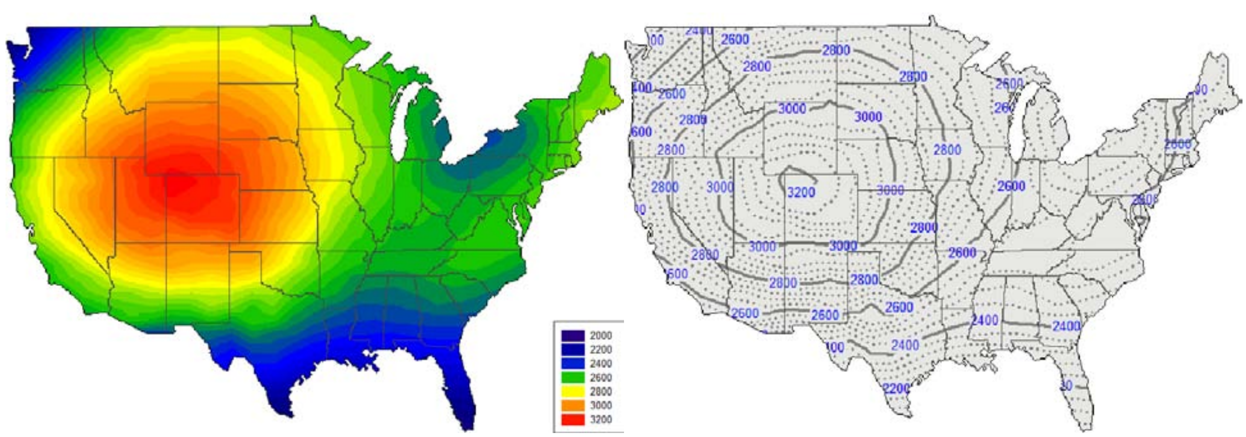
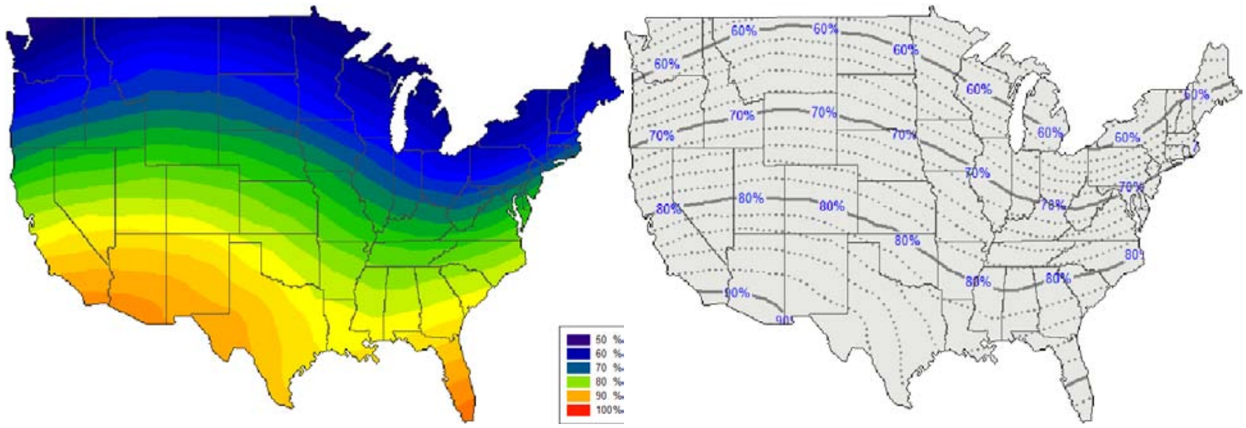


Figure A7. Annual fractional energy savings (%) for E64FPCL



Appendix B: *EGUSA* Auxiliary Natural Gas Water Heaters Contour Plots

Figure B1. Annual energy consumption in therms for a standard storage gas water heater

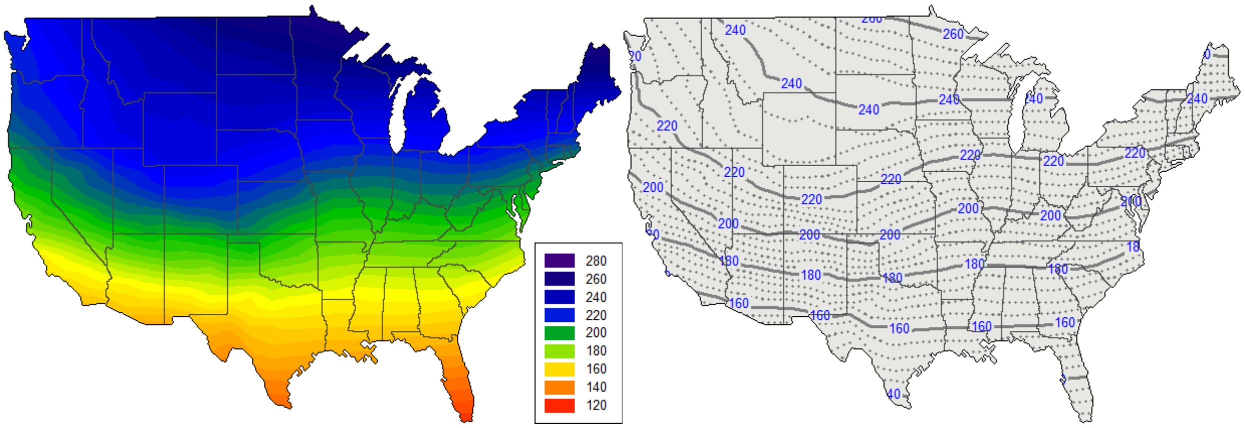


Figure B2. Annual absolute energy savings in therms for G32ICS

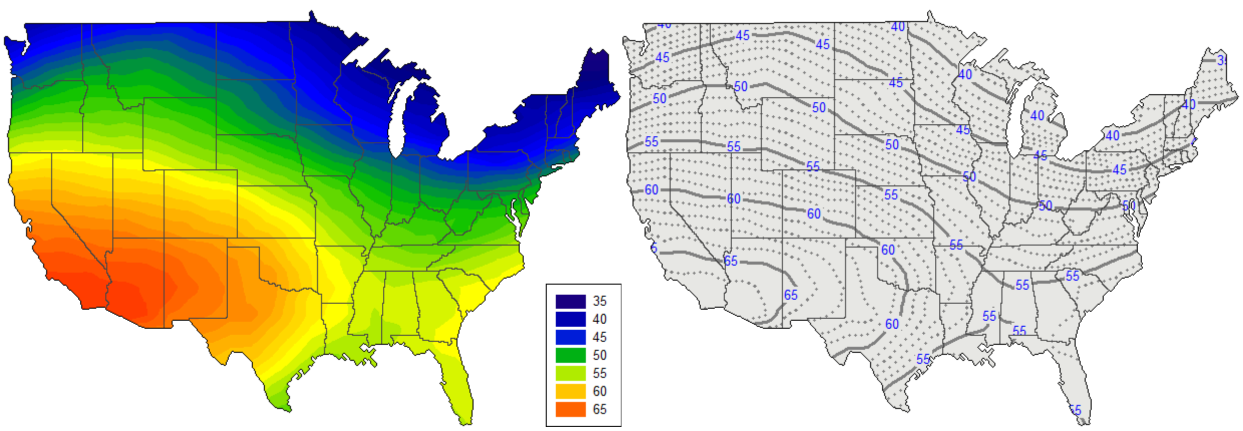


Figure B3. Annual fractional energy savings (%) for G32ICS

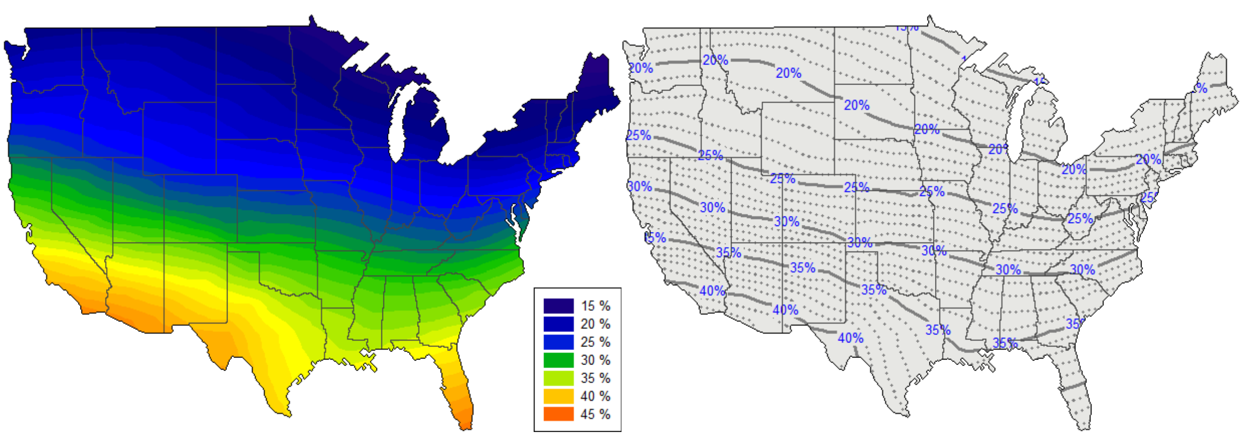


Figure B4. Annual absolute energy savings in therms for G40FPCL

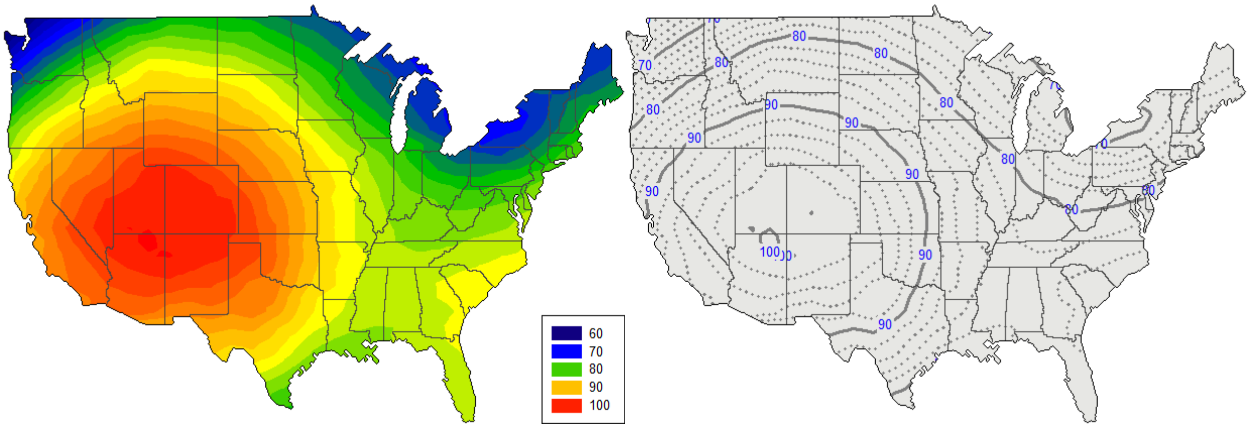


Figure B5. Annual fractional energy savings (%) for G40FPCL

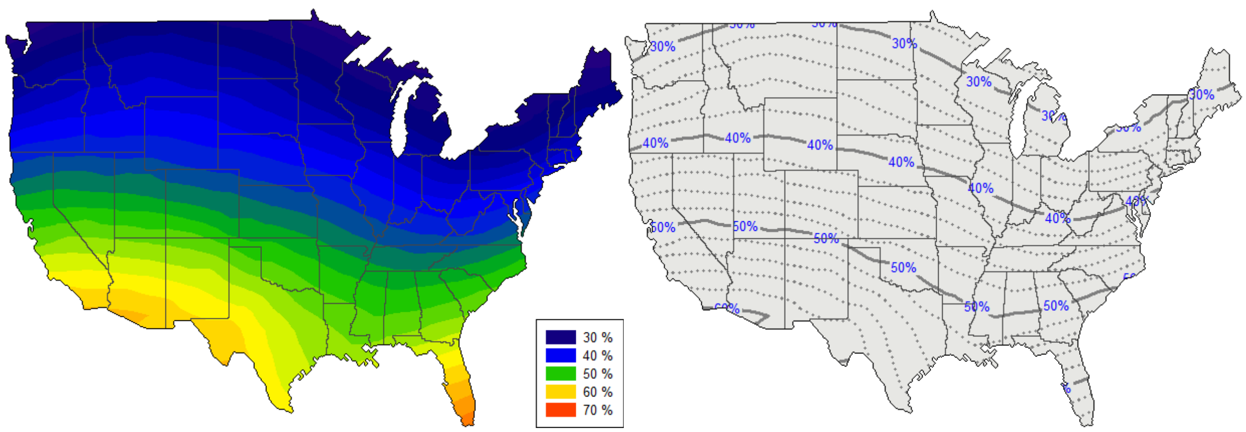


Figure B6. Annual absolute energy savings in therms for G64FPCL

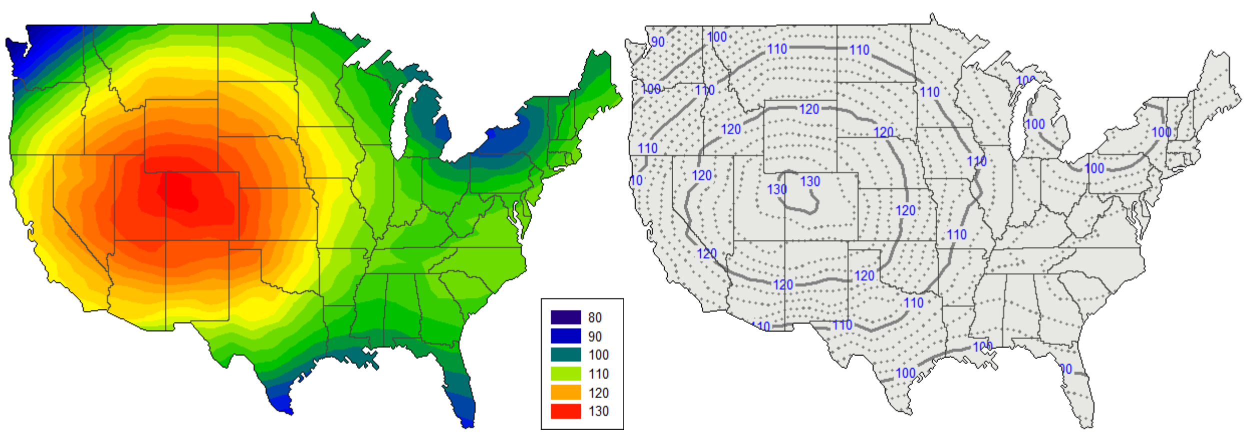
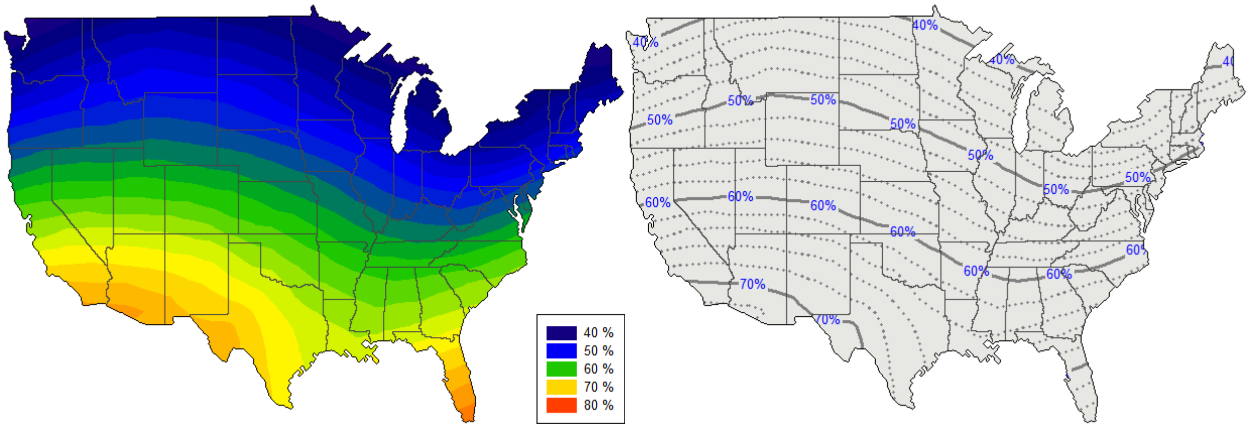


Figure B7. Annual fractional energy savings (%) for G64FPCL



Appendix C: *EGUSA* Summary of Auxiliary Systems Simulation Results

Table C1. *EGUSA* Summary of Auxiliary Electric Simulation Results

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		E	E32ICS		E40FPCL		E64FPCL	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
ALABAMA	BIRMINGHAM	3151	1592	50.5	2175	69.0	2564	81.4
	HUNTSVILLE	3351	1516	45.2	2158	64.4	2594	77.4
	MOBILE	2838	1559	54.9	2059	72.6	2367	83.4
	MONTGOMERY	3014	1647	54.6	2185	72.5	2529	83.9
ARIZONA	FLAGSTAFF	4422	1736	39.3	2923	66.1	3616	81.8
	PHOENIX	2154	1544	71.7	1905	88.4	2027	94.1
	PRESCOTT	3638	1986	54.6	2672	73.4	3132	86.1
	TUCSON	2665	1838	69.0	2269	85.1	2463	92.4
ARKANSAS	FORT SMITH	3337	1540	46.1	2130	63.8	2542	76.2
	LITTLE ROCK	3201	1535	48.0	2045	63.9	2430	75.9
CALIFORNIA	ARCATA	4038	1441	35.7	1966	48.7	2599	64.4
	BAKERSFIELD	2941	1706	58.0	2124	72.2	2387	81.2
	DAGGET	2754	1845	67.0	2288	83.1	2519	91.5
	FRESNO	3020	1697	56.2	2120	70.2	2390	79.1
	LONG BEACH	3104	1849	59.6	2357	75.9	2718	87.6
	LOS ANGELES	3196	1881	58.9	2405	75.3	2785	87.1
	SACRAMENTO	3314	1738	52.4	2248	67.8	2545	76.8
	SAN DIEGO	3234	1974	61.0	2572	79.5	2918	90.2
	SAN FRANCISCO	3617	1803	49.8	2379	65.8	2882	79.7
	SANTA MARIA	3673	2053	55.9	2739	74.6	3199	87.1
COLORADO	ALAMOSA	4780	1653	34.6	3051	63.8	3875	81.1
	COLORADO SPRINGS	4171	1635	39.2	2581	61.9	3237	77.6
	EAGLE	4647	1464	31.5	2561	55.1	3320	71.4
	GRAND JUNCTION	3834	1668	43.5	2514	65.6	3009	78.5
	PUEBLO	3890	1812	46.6	2642	67.9	3166	81.4
CONNECTICUT	BRIDGEPORT	3975	1277	32.1	1985	49.9	2562	64.5
	HARTFORD	4073	1183	29.0	1970	48.4	2557	62.8
DELAWARE	WILMINGTON	3807	1372	36.0	2087	54.8	2605	68.4
FLORIDA	DAYTONA BEACH	2566	1645	64.1	2086	81.3	2301	89.7
	JACKSONVILLE	2753	1569	57.0	2056	74.7	2347	85.3
	MIAMI	2127	1514	71.2	1878	88.3	2011	94.5
	TALLAHASSEE	2825	1587	56.2	2080	73.6	2373	84.0
	TAMPA	2424	1635	67.5	2047	84.4	2217	91.5
	WEST PALM BEACH	2256	1583	70.2	1975	87.5	2122	94.1
GEORGIA	ATHENS	3201	1597	49.9	2182	68.2	2567	80.2
	ATLANTA	3194	1595	49.9	2189	68.5	2558	80.1
	AUGUSTA	3106	1665	53.6	2220	71.5	2575	82.9
	COLUMBUS	2930	1564	53.4	2074	70.8	2396	81.8
	MACON	3037	1609	53.0	2136	70.3	2471	81.4
	SAVANNAH	2859	1602	56.0	2099	73.4	2390	83.6
IDAHO	BOISE	3957	1540	38.9	2219	56.1	2667	67.4
	POCATELLO	4351	1512	34.8	2386	54.8	2949	67.8
ILLINOIS	CHICAGO	3924	1214	30.9	1916	48.8	2419	61.6
	MOLINE	4105	1298	31.6	2138	52.1	2714	66.1
	PEORIA	4087	1335	32.7	2138	52.3	2696	66.0
	ROCKFORD	4308	1190	27.6	2050	47.6	2650	61.5
	SPRINGFIELD	3876	1372	35.4	2162	55.8	2680	69.1
INDIANA	EVANSVILLE	3616	1455	40.2	2107	58.3	2555	70.7
	FORT WAYNE	4166	1170	28.1	1954	46.9	2509	60.2
	INDIANAPOLIS	3977	1284	32.3	2053	51.6	2582	64.9
	SOUTH BEND	4032	1188	29.5	1908	47.3	2429	60.2
IOWA	DES MOINES	4085	1356	33.2	2237	54.8	2796	68.4
	MASON CITY	4488	1193	26.6	2100	46.8	2745	61.2
	SIOUX CITY	4189	1327	31.7	2207	52.7	2780	66.4

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	WATERLOO	4306	1248	29.0	2116	49.1	2721	63.2
KANSAS	DODGE CITY	3751	1652	44.0	2483	66.2	2970	79.2
	GOODLAND	4054	1669	41.2	2616	64.5	3178	78.4
	TOPEKA	3731	1438	38.5	2233	59.8	2747	73.6
	WICHITA	3575	1603	44.8	2321	64.9	2776	77.7
KENTUCKY	COVINGTON	3871	1307	33.8	1998	51.6	2518	65.0
	LEXINGTON	3758	1319	35.1	2013	53.6	2511	66.8
	LOUISVILLE	3518	1221	34.7	1772	50.4	2228	63.3
LOUISIANA	BATON ROUGE	2828	1488	52.6	1956	69.2	2257	79.8
	LAKE CHARLES	2805	1531	54.6	2009	71.6	2310	82.4
	NEW ORLEANS	2671	1507	56.4	1964	73.5	2243	84.0
	SHREVEPORT	2998	1516	50.6	2022	67.4	2347	78.3
MAINE	CARIBOU	4981	869	17.4	1763	35.4	2461	49.4
	PORTLAND	4497	1193	26.5	2160	48.0	2847	63.3
MARYLAND	BALTIMORE	3678	1414	38.4	2113	57.4	2621	71.3
MASSACHUSETTS	BOSTON	4047	1265	31.3	2058	50.9	2637	65.2
	WORCESTER	4407	1156	26.2	2094	47.5	2774	62.9
MICHIGAN	ALPENA	4621	1021	22.1	1936	41.9	2578	55.8
	DETROIT	4093	1101	26.9	1779	43.5	2316	56.6
	FLINT	4315	1110	25.7	1872	43.4	2453	56.8
	GRAND RAPIDS	4290	1163	27.1	1895	44.2	2446	57.0
	HOUGHTON LAKE	4572	995	21.8	1751	38.3	2345	51.3
	LANSING	4306	1163	27.0	1900	44.1	2476	57.5
	MUSKEGON	4325	1151	26.6	1875	43.4	2411	55.7
	SAULT STE. MARIE	4881	989	20.3	1931	39.6	2622	53.7
	TRAVERSE CITY	4496	1048	23.3	1813	40.3	2411	53.6
MINNESOTA	DULUTH	4964	1037	20.9	2001	40.3	2720	54.8
	INTERNATIONAL FALLS	5050	993	19.7	1847	36.6	2538	50.3
	MINNEAPOLIS	4438	1155	26.0	2094	47.2	2715	61.2
	ROCHESTER	4617	1130	24.5	1996	43.2	2643	57.2
	SAINT CLOUD	4754	1167	24.5	2154	45.3	2863	60.2
MISSISSIPPI	JACKSON	3046	1612	52.9	2145	70.4	2491	81.8
	MERIDIAN	3033	1550	51.1	2071	68.3	2435	80.3
MISSOURI	COLUMBIA	3836	1449	37.8	2224	58.0	2733	71.2
	KANSAS CITY	3837	1441	37.6	2275	59.3	2803	73.1
	SPRINGFIELD	3683	1463	39.7	2165	58.8	2639	71.7
	ST. LOUIS	3642	1399	38.4	2126	58.4	2602	71.4
MONTANA	BILLINGS	4284	1410	32.9	2235	52.2	2810	65.6
	CUT BANK	4656	1351	29.0	2274	48.8	2955	63.5
	GLASGOW	4577	1277	27.9	2159	47.2	2771	60.5
	GREAT FALLS	4534	1387	30.6	2185	48.2	2821	62.2
	HELENA	4521	1305	28.9	2203	48.7	2838	62.8
	KALISPELL	4606	1171	25.4	1907	41.4	2479	53.8
	LEWISTON	4633	1255	27.1	2179	47.0	2856	61.6
	MILES CITY	4421	1414	32.0	2291	51.8	2882	65.2
	MISSOULA	4474	1271	28.4	1969	44.0	2542	56.8
NEBRASKA	GRAND ISLAND	4162	1413	34.0	2361	56.7	2956	71.0
	NORFOLK	4229	1365	32.3	2311	54.6	2897	68.5
	NORTH PLATTE	4218	1471	34.9	2431	57.6	3054	72.4
	SCOTTSBLUFF	4226	1486	35.2	2456	58.1	3068	72.6
NEVADA	ELKO	4354	1588	36.5	2587	59.4	3186	73.2
	ELY	4479	1503	33.6	2784	62.2	3486	77.8
	LAS VEGAS	2732	1774	64.9	2258	82.7	2484	90.9
	RENO	3974	1814	45.6	2645	66.6	3147	79.2
	TONOPAH	3961	1831	46.2	2782	70.2	3281	82.8
	WINNEMUCCA	4091	1687	41.2	2589	63.3	3112	76.1
NEW HAMPSHIRE	CONCORD	4414	1139	25.8	2033	46.1	2674	60.6
NEW JERSEY	ATLANTIC CITY	3840	1411	36.7	2166	56.4	2723	70.9
	NEWARK	3774	1288	34.1	2032	53.8	2564	67.9
NEW MEXICO	ALBUQUERQUE	3612	2001	55.4	2769	76.7	3187	88.2

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	TUCUMCARI	3589	1843	51.4	2631	73.3	3075	85.7
NEW YORK	ALBANY	4267	1194	28.0	2029	47.6	2641	61.9
	BINGHAMTON	4374	1073	24.5	1887	43.1	2511	57.4
	BUFFALO	4262	1128	26.5	1868	43.8	2428	57.0
	MASSENA	4542	1090	24.0	1956	43.1	2606	57.4
	NEW YORK CITY	3776	1371	36.3	2028	53.7	2523	66.8
	ROCHESTER	4209	1133	26.9	1837	43.6	2384	56.6
	SYRACUSE	4241	1139	26.9	1897	44.7	2470	58.2
NORTH CAROLINA	ASHEVILLE	3740	1559	41.7	2276	60.9	2824	75.5
	CAPE HATTERAS	3128	1599	51.1	2134	68.2	2488	79.5
	CHARLOTTE	3287	1615	49.1	2217	67.4	2627	79.9
	GREENSBORO	3504	1487	42.4	2156	61.5	2622	74.8
	RALEIGH	3388	1561	46.1	2165	63.9	2604	76.9
	WILMINGTON	3094	1585	51.2	2119	68.5	2485	80.3
NORTH DAKOTA	BISMARCK	4640	1307	28.2	2189	47.2	2825	60.9
	FARGO	4789	1186	24.8	2130	44.5	2805	58.6
	MINOT	4758	1158	24.3	1990	41.8	2643	55.5
OHIO	AKRON	4156	1126	27.1	1799	43.3	2343	56.4
	CLEVELAND	4082	1041	25.5	1664	40.8	2178	53.4
	COLUMBUS	3980	1236	31.1	1923	48.3	2462	61.9
	DAYTON	4029	1218	30.2	1951	48.4	2490	61.8
	MANSFIELD	4228	1130	26.7	1874	44.3	2454	58.0
	TOLEDO	4202	1252	29.8	1995	47.5	2572	61.2
	YOUNGSTOWN	4245	1122	26.4	1770	41.7	2332	54.9
OKLAHOMA	OKLAHOMA CITY	3373	1534	45.5	2172	64.4	2553	75.7
	TULSA	3335	1523	45.7	2181	65.4	2591	77.7
OREGON	ASTORIA	4026	1118	27.8	1606	39.9	2139	53.1
	BURNS	4453	1471	33.0	2399	53.9	2998	67.3
	EUGENE	3966	1291	32.6	1796	45.3	2250	56.7
	MEDFORD	3856	1585	41.1	2149	55.7	2582	67.0
	NORTH BEND	3972	1468	37.0	2061	51.9	2631	66.2
	PENDLETON	3960	1521	38.4	2102	53.1	2546	64.3
	PORTLAND	3825	1221	31.9	1705	44.6	2148	56.2
	REDMOND	4305	1590	36.9	2339	54.3	2893	67.2
	SALEM	3897	1288	33.1	1807	46.4	2267	58.2
PENNSYLVANIA	ALLENTOWN	3991	1236	31.0	2005	50.2	2572	64.4
	BRADFORD	4635	1057	22.8	1861	40.2	2530	54.6
	ERIE	4202	1114	26.5	1786	42.5	2304	54.8
	HARRISBURG	3912	1275	32.6	2036	52.0	2596	66.4
	PHILADELPHIA	3744	1391	37.2	2090	55.8	2602	69.5
	PITTSBURGH	4049	1184	29.2	1894	46.8	2433	60.1
	WILKES-BARRE	4143	1162	28.0	1911	46.1	2486	60.0
	WILLIAMSPORT	4029	1169	29.0	1898	47.1	2461	61.1
RHODE ISLAND	PROVIDENCE	4056	1252	30.9	2031	50.1	2627	64.8
SOUTH CAROLINA	CHARLESTON	2945	1614	54.8	2134	72.5	2460	83.5
	COLUMBIA	3105	1578	50.8	2119	68.2	2484	80.0
	GREENVILLE	3457	1436	41.5	2104	60.9	2557	74.0
SOUTH DAKOTA	HURON	4548	1288	28.3	2248	49.4	2905	63.9
	PIERRE	4303	1397	32.5	2226	51.7	2817	65.5
	RAPID CITY	4362	1459	33.4	2424	55.6	3060	70.2
	SIOUX FALLS	4420	1291	29.2	2191	49.6	2818	63.8
TENNESSEE	BRISTOL	3717	1431	38.5	2128	57.3	2645	71.2
	CHATTANOOGA	3323	1502	45.2	2081	62.6	2507	75.4
	KNOXVILLE	3503	1420	40.5	2100	59.9	2565	73.2
	MEMPHIS	3138	1540	49.1	2074	66.1	2422	77.2
	NASHVILLE	3373	1467	43.5	2095	62.1	2511	74.4
TEXAS	ABILENE	2829	1761	62.2	2314	81.8	2550	90.1
	AMARILLO	3595	1830	50.9	2574	71.6	3025	84.1
	AUSTIN	2661	1465	55.1	1902	71.5	2172	81.6
	BROWNSVILLE	2369	1421	60.0	1815	76.6	2022	85.4

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	CORPUS CHRISTI	2499	1437	57.5	1854	74.2	2099	84.0
	EL PASO	3011	1990	66.1	2544	84.5	2783	92.4
	FORT WORTH	3045	1575	51.7	2119	69.6	2456	80.7
	HOUSTON	2681	1481	55.2	1943	72.5	2234	83.3
	LUBBOCK	3369	1796	53.3	2463	73.1	2855	84.7
	LUFKIN	2882	1561	54.2	2048	71.1	2360	81.9
	MIDLAND	3092	1848	59.8	2421	78.3	2723	88.1
	PORT ARTHUR	2693	1501	55.7	1951	72.4	2227	82.7
	SAN ANGELO	3036	1767	58.2	2325	76.6	2629	86.6
	SAN ANTONIO	2676	1605	60.0	2061	77.0	2313	86.4
	VICTORIA	2638	1511	57.3	1969	74.6	2233	84.6
	WACO	2886	1607	55.7	2127	73.7	2436	84.4
	WICHITA FALLS	3092	1666	53.9	2235	72.3	2573	83.2
UTAH	CEDAR CITY	4014	1793	44.7	2767	68.9	3298	82.2
	SALT LAKE CITY	3866	1551	40.1	2270	58.7	2735	70.7
VERMONT	BURLINGTON	4424	1122	25.4	1897	42.9	2506	56.6
VIRGINIA	LYNCHBURG	3584	1538	42.9	2232	62.3	2709	75.6
	NORFOLK	3343	1483	44.4	2110	63.1	2540	76.0
	RICHMOND	3471	1515	43.6	2163	62.3	2628	75.7
	ROANOKE	3629	1464	40.3	2175	59.9	2675	73.7
	WASHINGTON D.C.	3550	1358	38.3	2010	56.6	2468	69.5
WASHINGTON	OLYMPIA	4092	1077	26.3	1556	38.0	2051	50.1
	QUILLAYUTE	4189	1022	24.4	1473	35.2	2002	47.8
	SEATTLE	3965	1190	30.0	1676	42.3	2147	54.1
	SPOKANE	4182	1259	30.1	1894	45.3	2353	56.3
	YAKIMA	4133	1467	35.5	2117	51.2	2604	63.0
WEST VIRGINIA	CHARLESTON	3744	1346	36.0	2006	53.6	2512	67.1
	ELKINS	4170	1181	28.3	1884	45.2	2493	59.8
	HUNTINGTON	3719	1337	36.0	1976	53.1	2486	66.8
WISCONSIN	EAU CLAIRE	4605	1152	25.0	2078	45.1	2758	59.9
	GREEN BAY	4491	1120	24.9	2039	45.4	2690	59.9
	LA CROSSE	4370	1195	27.3	2071	47.4	2687	61.5
	MILWAUKEE	4394	1185	27.0	2060	46.9	2693	61.3
WYOMING	CASPER	4443	1430	32.2	2513	56.6	3179	71.6
	CHEYENNE	4480	1460	32.6	2559	57.1	3284	73.3
	LANDER	4463	1539	34.5	2651	59.4	3322	74.4
	ROCK SPRINGS	4618	1453	31.5	2646	57.3	3363	72.8
	SHERIDAN	4399	1451	33.0	2332	53.0	2960	67.3

Table C2. *EGUSA* Summary of Auxiliary Natural Gas Simulation Results

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
ALABAMA	BIRMINGHAM	176	56	31.8	85	48.3	108	61.4
	HUNTSVILLE	186	53	28.5	83	44.6	107	57.5
	MOBILE	159	54	34.0	82	51.6	102	64.2
	MONTGOMERY	169	58	34.3	87	51.5	109	64.5
ARIZONA	FLAGSTAFF	242	60	24.8	109	45.0	147	60.7
	PHOENIX	124	58	46.8	84	67.7	95	76.6
	PRESCOTT	201	70	34.8	104	51.7	132	65.7
	TUCSON	150	67	44.7	95	63.3	111	74.0
ARKANSAS	FORT SMITH	186	55	29.6	83	44.6	106	57.0
	LITTLE ROCK	178	54	30.3	79	44.4	101	56.7
CALIFORNIA	ARCATA	222	50	22.5	73	32.9	103	46.4
	BAKERSFIELD	165	62	37.6	88	53.3	104	63.0
	DAGGET	155	67	43.2	96	61.9	112	72.3
	FRESNO	169	62	36.7	87	51.5	104	61.5
	LONG BEACH	173	64	37.0	93	53.8	117	67.6
	LOS ANGELES	178	65	36.5	94	52.8	120	67.4
	SACRAMENTO	184	62	33.7	91	49.5	109	59.2
	SAN DIEGO	180	69	38.3	102	56.7	127	70.6
	SAN FRANCISCO	200	62	31.0	91	45.5	120	60.0
	SANTA MARIA	203	71	35.0	106	52.2	136	67.0
COLORADO	ALAMOSA	261	57	21.8	113	43.3	154	59.0
	COLORADO SPRINGS	229	57	24.9	96	41.9	130	56.8
	EAGLE	254	51	20.1	94	37.0	131	51.6
	GRAND JUNCTION	211	59	28.0	96	45.5	124	58.8
	PUEBLO	214	63	29.4	100	46.7	130	60.7
CONNECTICUT	BRIDGEPORT	219	44	20.1	74	33.8	102	46.6
	HARTFORD	224	41	18.3	73	32.6	101	45.1
DELAWARE	WILMINGTON	210	47	22.4	78	37.1	105	50.0
FLORIDA	DAYTONA BEACH	145	58	40.0	86	59.3	103	71.0
	JACKSONVILLE	155	55	35.5	83	53.5	102	65.8
	MIAMI	122	53	43.4	81	66.4	93	76.2
	TALLAHASSEE	159	56	35.2	84	52.8	104	65.4
	TAMPA	138	59	42.8	87	63.0	101	73.2
	WEST PALM BEACH	129	56	43.4	84	65.1	98	76.0
GEORGIA	ATHENS	178	56	31.5	85	47.8	108	60.7
	ATLANTA	178	56	31.5	86	48.3	109	61.2
	AUGUSTA	173	58	33.5	87	50.3	110	63.6
	COLUMBUS	164	55	33.5	82	50.0	103	62.8
	MACON	170	57	33.5	85	50.0	106	62.4
	SAVANNAH	161	57	35.4	85	52.8	104	64.6
IDAHO	BOISE	218	54	24.8	86	39.4	110	50.5
	POCATELLO	239	53	22.2	90	37.7	120	50.2
ILLINOIS	CHICAGO	217	43	19.8	73	33.6	97	44.7
	MOLINE	226	45	19.9	80	35.4	108	47.8
	PEORIA	225	47	20.9	80	35.6	108	48.0
	ROCKFORD	236	41	17.4	75	31.8	104	44.1
	SPRINGFIELD	214	48	22.4	82	38.3	109	50.9
INDIANA	EVANSVILLE	200	51	25.5	80	40.0	105	52.5
	FORT WAYNE	229	41	17.9	73	31.9	99	43.2
	INDIANAPOLIS	219	45	20.5	77	35.2	104	47.5
	SOUTH BEND	222	41	18.5	71	32.0	97	43.7
IOWA	DES MOINES	225	47	20.9	84	37.3	112	49.8
	MASON CITY	246	41	16.7	77	31.3	108	43.9
	SIOUX CITY	230	46	20.0	82	35.7	111	48.3
	WATERLOO	236	43	18.2	78	33.1	107	45.3
KANSAS	DODGE CITY	207	58	28.0	95	45.9	123	59.4
	GOODLAND	223	58	26.0	99	44.4	130	58.3

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
	TOPEKA	206	50	24.3	85	41.3	111	53.9
	WICHITA	198	57	28.8	90	45.5	115	58.1
KENTUCKY	COVINGTON	241	73	30.3	103	42.7	129	53.5
	LEXINGTON	208	46	22.1	76	36.5	102	49.0
	LOUISVILLE	195	43	22.1	67	34.4	90	46.2
LOUISIANA	BATON ROUGE	159	53	33.3	78	49.1	97	61.0
	LAKE CHARLES	158	54	34.2	81	51.3	100	63.3
	NEW ORLEANS	151	53	35.1	80	53.0	98	64.9
	SHREVEPORT	168	55	32.7	81	48.2	100	59.5
MAINE	CARIBOU	272	30	11.0	64	23.5	93	34.2
	PORTLAND	246	41	16.7	79	32.1	111	45.1
MARYLAND	BALTIMORE	203	49	24.1	80	39.4	106	52.2
MASSACHUSETTS	BOSTON	223	44	19.7	77	34.5	105	47.1
	WORCESTER	242	40	16.5	77	31.8	109	45.0
MICHIGAN	ALPENA	253	36	14.2	71	28.1	101	39.9
	DETROIT	225	38	16.9	66	29.3	91	40.4
	FLINT	237	39	16.5	69	29.1	97	40.9
	GRAND RAPIDS	235	40	17.0	70	29.8	96	40.9
	HOUGHTON LAKE	250	34	13.6	64	25.6	91	36.4
	LANSING	236	40	16.9	70	29.7	97	41.1
	MUSKEGON	237	40	16.9	69	29.1	96	40.5
	SAULT STE. MARIE	266	34	12.8	70	26.3	101	38.0
	TRAVERSE CITY	246	36	14.6	66	26.8	94	38.2
MINNESOTA	DULUTH	271	36	13.3	73	26.9	105	38.7
	INTERNATIONAL FALLS	275	34	12.4	67	24.4	97	35.3
	MINNEAPOLIS	243	40	16.5	77	31.7	107	44.0
	ROCHESTER	253	39	15.4	73	28.9	103	40.7
	SAINT CLOUD	260	41	15.8	79	30.4	111	42.7
MISSISSIPPI	JACKSON	170	57	33.5	85	50.0	106	62.4
	MERIDIAN	169	54	32.0	81	47.9	103	60.9
MISSOURI	COLUMBIA	212	51	24.1	85	40.1	111	52.4
	KANSAS CITY	212	51	24.1	86	40.6	114	53.8
	SPRINGFIELD	204	52	25.5	83	40.7	108	52.9
	ST. LOUIS	202	49	24.3	81	40.1	107	53.0
MONTANA	BILLINGS	235	49	20.9	83	35.3	112	47.7
	CUT BANK	255	47	18.4	84	32.9	117	45.9
	GLASGOW	250	44	17.6	79	31.6	109	43.6
	GREAT FALLS	248	48	19.4	81	32.7	111	44.8
	HELENA	247	45	18.2	81	32.8	112	45.3
	KALISPELL	252	41	16.3	71	28.2	98	38.9
	LEWISTON	253	43	17.0	80	31.6	112	44.3
	MILES CITY	242	49	20.2	85	35.1	114	47.1
	MISSOULA	245	44	18.0	73	29.8	101	41.2
NEBRASKA	GRAND ISLAND	229	50	21.8	89	38.9	119	52.0
	NORFOLK	232	47	20.3	86	37.1	116	50.0
	NORTH PLATTE	232	52	22.4	91	39.2	123	53.0
	SCOTTSBLUFF	232	52	22.4	92	39.7	123	53.0
NEVADA	ELKO	238	55	23.1	97	40.8	128	53.8
	ELY	245	52	21.2	103	42.0	140	57.1
	LAS VEGAS	154	65	42.2	95	61.7	110	71.4
	RENO	219	64	29.2	102	46.6	130	59.4
	TONOPAH	218	64	29.4	107	49.1	136	62.4
	WINNEMUCCA	225	60	26.7	99	44.0	128	56.9
NEW HAMPSHIRE	CONCORD	242	40	16.5	75	31.0	105	43.4
	ATLANTIC CITY	212	49	23.1	82	38.7	110	51.9
	NEWARK	209	45	21.5	77	36.8	103	49.3
NEW MEXICO	ALBUQUERQUE	200	71	35.5	109	54.5	136	68.0
	TUCUMCARI	199	65	32.7	103	51.8	130	65.3
NEW YORK	ALBANY	234	41	17.5	75	32.1	104	44.4
	BINGHAMTON	240	37	15.4	69	28.8	98	40.8

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	G32ICS		G40FPCL		G64FPCL	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
	BUFFALO	234	39	16.7	69	29.5	96	41.0
	MASSENA	249	38	15.3	72	28.9	102	41.0
	NEW YORK CITY	209	48	23.0	77	36.8	103	49.3
	ROCHESTER	231	39	16.9	68	29.4	94	40.7
	SYRACUSE	233	40	17.2	70	30.0	97	41.6
NORTH CAROLINA	ASHEVILLE	207	55	26.6	86	41.5	116	56.0
	CAPE HATTERAS	175	56	32.0	84	48.0	106	60.6
	CHARLOTTE	183	57	31.1	86	47.0	111	60.7
	GREENSBORO	194	52	26.8	82	42.3	108	55.7
	RALEIGH	188	54	28.7	83	44.1	108	57.4
	WILMINGTON	173	56	32.4	84	48.6	106	61.3
NORTH DAKOTA	BISMARCK	254	46	18.1	81	31.9	111	43.7
	FARGO	262	41	15.6	78	29.8	109	41.6
	MINOT	260	40	15.4	73	28.1	103	39.6
OHIO	AKRON	228	39	17.1	66	28.9	92	40.4
	CLEVELAND	225	36	16.0	62	27.6	86	38.2
	COLUMBUS	219	43	19.6	72	32.9	98	44.7
	DAYTON	222	43	19.4	73	32.9	100	45.0
	MANSFIELD	232	39	16.8	69	29.7	96	41.4
	TOLEDO	231	44	19.0	74	32.0	102	44.2
	YOUNGSTOWN	233	39	16.7	65	27.9	91	39.1
OKLAHOMA	OKLAHOMA CITY	188	55	29.3	85	45.2	108	57.4
	TULSA	186	55	29.6	86	46.2	109	58.6
OREGON	ASTORIA	222	39	17.6	60	27.0	85	38.3
	BURNS	244	52	21.3	90	36.9	121	49.6
	EUGENE	218	45	20.6	67	30.7	91	41.7
	MEDFORD	212	55	25.9	83	39.2	106	50.0
	NORTH BEND	219	51	23.3	78	35.6	106	48.4
	PENDLETON	218	53	24.3	81	37.2	104	47.7
	PORTLAND	211	43	20.4	64	30.3	87	41.2
	REDMOND	236	55	23.3	88	37.3	117	49.6
	SALEM	215	45	20.9	69	32.1	92	42.8
PENNSYLVANIA	ALLENTOWN	220	43	19.5	75	34.1	102	46.4
	BRADFORD	253	36	14.2	67	26.5	97	38.3
	ERIE	231	39	16.9	66	28.6	92	39.8
	HARRISBURG	216	45	20.8	76	35.2	104	48.1
	PHILADELPHIA	207	48	23.2	79	38.2	105	50.7
	PITTSBURGH	223	41	18.4	71	31.8	97	43.5
	WILKES-BARRE	228	41	18.0	71	31.1	98	43.0
	WILLIAMSPORT	222	41	18.5	71	32.0	98	44.1
RHODE ISLAND	PROVIDENCE	223	43	19.3	75	33.6	104	46.6
SOUTH CAROLINA	CHARLESTON	165	57	34.5	85	51.5	106	64.2
	COLUMBIA	173	55	31.8	83	48.0	105	60.7
	GREENVILLE	192	50	26.0	81	42.2	106	55.2
SOUTH DAKOTA	HURON	249	45	18.1	83	33.3	114	45.8
	PIERRE	236	48	20.3	83	35.2	112	47.5
	RAPID CITY	239	50	20.9	90	37.7	121	50.6
	SIOUX FALLS	242	45	18.6	81	33.5	111	45.9
TENNESSEE	BRISTOL	205	50	24.4	80	39.0	107	52.2
	CHATTANOOGA	185	53	28.6	81	43.8	105	56.8
	KNOXVILLE	194	50	25.8	80	41.2	105	54.1
	MEMPHIS	175	54	30.9	82	46.9	103	58.9
	NASHVILLE	187	51	27.3	81	43.3	104	55.6
TEXAS	ABILENE	159	64	40.3	96	60.4	113	71.1
	AMARILLO	199	64	32.2	100	50.3	127	63.8
	AUSTIN	150	52	34.7	77	51.3	95	63.3
	BROWNSVILLE	135	51	37.8	76	56.3	90	66.7
	CORPUS CHRISTI	142	51	35.9	76	53.5	93	65.5
	EL PASO	168	71	42.3	104	61.9	123	73.2
	FORT WORTH	170	56	32.9	84	49.4	105	61.8

EGUSA Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
	HOUSTON	151	52	34.4	78	51.7	97	64.2
	LUBBOCK	187	63	33.7	97	51.9	121	64.7
	LUFKIN	162	56	34.6	82	50.6	102	63.0
	MIDLAND	173	66	38.2	98	56.6	119	68.8
	PORT ARTHUR	152	53	34.9	79	52.0	97	63.8
	SAN ANGELO	170	63	37.1	94	55.3	114	67.1
	SAN ANTONIO	151	58	38.4	85	56.3	102	67.5
	VICTORIA	149	53	35.6	80	53.7	98	65.8
	WACO	162	57	35.2	86	53.1	105	64.8
	WICHITA FALLS	173	60	34.7	90	52.0	110	63.6
UTAH	CEDAR CITY	221	63	28.5	106	48.0	137	62.0
	SALT LAKE CITY	213	55	25.8	87	40.8	112	52.6
VERMONT	BURLINGTON	242	38	15.7	69	28.5	97	40.1
VIRGINIA	LYNCHBURG	198	53	26.8	85	42.9	111	56.1
	NORFOLK	186	52	28.0	81	43.5	106	57.0
	RICHMOND	193	53	27.5	83	43.0	109	56.5
	ROANOKE	201	51	25.4	83	41.3	110	54.7
	WASHINGTON D.C.	197	48	24.4	77	39.1	101	51.3
WASHINGTON	OLYMPIA	225	37	16.4	58	25.8	81	36.0
	QUILLAYUTE	230	35	15.2	54	23.5	78	33.9
	SEATTLE	218	41	18.8	63	28.9	86	39.4
	SPOKANE	229	44	19.2	71	31.0	94	41.0
	YAKIMA	227	51	22.5	80	35.2	106	46.7
WEST VIRGINIA	CHARLESTON	207	47	22.7	76	36.7	102	49.3
	ELKINS	229	41	17.9	69	30.1	98	42.8
	HUNTINGTON	205	46	22.4	74	36.1	100	48.8
WISCONSIN	EAU CLAIRE	252	40	15.9	76	30.2	107	42.5
	GREEN BAY	246	39	15.9	75	30.5	105	42.7
	LA CROSSE	240	42	17.5	77	32.1	106	44.2
	MILWAUKEE	241	41	17.0	76	31.5	106	44.0
WYOMING	CASPER	243	49	20.2	93	38.3	126	51.9
	CHEYENNE	245	50	20.4	94	38.4	130	53.1
	LANDER	244	53	21.7	99	40.6	133	54.5
	ROCK SPRINGS	252	50	19.8	97	38.5	133	52.8
	SHERIDAN	241	50	20.7	87	36.1	118	49.0

Appendix D: *BEopt* Summary of Auxiliary Electric and Natural Gas Simulations Results

Table D1. *BEopt* Summary of Auxiliary Electric Simulations Results

BEopt Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
ALABAMA	BIRMINGHAM	3129	1733	55.4	2230	71.3	2608	83.3
	MOBILE	2836	1675	59.1	2113	74.5	2419	85.3
	MONTGOMERY	2998	1763	58.8	2240	74.7	2567	85.6
ARIZONA	FLAGSTAFF	4293	2298	53.5	3080	71.7	3702	86.2
	PHOENIX	2250	1699	75.5	1938	86.1	2082	92.5
	PRESCOTT	3575	2221	62.1	2841	79.5	3209	89.8
	TUCSON	2686	2008	74.8	2350	87.5	2508	93.4
ARKANSAS	FORT SMITH	3304	1773	53.7	2274	68.8	2653	80.3
	LITTLE ROCK	3246	1572	48.4	2067	63.7	2470	76.1
CALIFORNIA	ARCATA	3933	1624	41.3	2176	55.3	2795	71.1
	BAKERSFIELD	2931	1849	63.1	2183	74.5	2438	83.2
	FRESNO	3009	1835	61.0	2188	72.7	2440	81.1
	LONG BEACH	3063	1966	64.2	2463	80.4	2779	90.7
	LOS ANGELES	3146	2006	63.8	2527	80.3	2846	90.5
	SACRAMENTO	3267	1910	58.5	2327	71.2	2599	79.6
	SAN DIEGO	3033	2064	68.1	2547	84.0	2811	92.7
	SAN FRANCISCO	3542	1953	55.1	2543	71.8	2985	84.3
COLORADO	ALAMOSA	4626	2472	53.4	3331	72.0	3997	86.4
	COLORADO SPRINGS	4065	2100	51.7	2801	68.9	3361	82.7
	EAGLE	4506	2087	46.3	2839	63.0	3490	77.5
	GRAND JUNCTION	3758	2074	55.2	2666	70.9	3082	82.0
	PUEBLO	3806	2174	57.1	2826	74.3	3260	85.7
CONNECTICUT	BRIDGEPORT	3883	1637	42.2	2179	56.1	2729	70.3
	HARTFORD	3973	1577	39.7	2128	53.6	2679	67.4
DELAWARE	WILMINGTON	3732	1660	44.5	2217	59.4	2706	72.5
FLORIDA	DAYTONA BEACH	2573	1741	67.7	2132	82.9	2332	90.6
	JACKSONVILLE	2753	1661	60.3	2122	77.1	2411	87.6
	MIAMI	2159	1603	74.2	1879	87.0	2022	93.7
	TALLAHASSEE	2823	1689	59.8	2155	76.3	2438	86.4
	TAMPA	2442	1746	71.5	2080	85.2	2245	91.9
	WEST PALM BEACH	2281	1673	73.3	1979	86.8	2118	92.9
GEORGIA	ATHENS	3180	1751	55.1	2278	71.6	2653	83.4
	ATLANTA	3170	1768	55.8	2267	71.5	2636	83.2
	AUGUSTA	3084	1786	57.9	2295	74.4	2627	85.2
	COLUMBUS	2926	1696	58.0	2147	73.4	2453	83.8
	MACON	3022	1727	57.1	2194	72.6	2523	83.5
	SAVANNAH	2855	1709	59.9	2171	76.0	2460	86.2
IDAHO	BOISE	3870	1827	47.2	2393	61.8	2797	72.3
	POCATELLO	4230	1931	45.7	2587	61.2	3060	72.3
ILLINOIS	CHICAGO	4025	1604	39.9	2155	53.5	2663	66.2
	MOLINE	4004	1695	42.3	2280	56.9	2803	70.0
	PEORIA	3990	1708	42.8	2289	57.4	2791	69.9
	ROCKFORD	4193	1653	39.4	2237	53.4	2782	66.3
	SPRINGFIELD	3797	1727	45.5	2304	60.7	2795	73.6
INDIANA	EVANSVILLE	3554	1689	47.5	2218	62.4	2654	74.7
	FORT WAYNE	4062	1582	38.9	2145	52.8	2651	65.3
	INDIANAPOLIS	3888	1651	42.5	2213	56.9	2691	69.2
	SOUTH BEND	3934	1531	38.9	2075	52.7	2556	65.0
IOWA	DES MOINES	3990	1783	44.7	2381	59.7	2877	72.1
	MASON CITY	4356	1693	38.9	2307	53.0	2885	66.2
	SIOUX CITY	4090	1771	43.3	2386	58.3	2910	71.1
	WATERLOO	4191	1694	40.4	2313	55.2	2863	68.3
KANSAS	DODGE CITY	3684	2002	54.3	2636	71.6	3075	83.5
	GOODLAND	3955	2088	52.8	2758	69.7	3255	82.3

***BEopt* Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters**								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	TOPEKA	3665	1771	48.3	2344	64.0	2833	77.3
	WICHITA	3521	1874	53.2	2438	69.2	2869	81.5
KENTUCKY	LEXINGTON	3683	1598	43.4	2144	58.2	2613	70.9
	LOUISVILLE	3470	1422	41.0	1929	55.6	2405	69.3
LOUISIANA	BATON ROUGE	2823	1589	56.3	2005	71.0	2304	81.6
	LAKE CHARLES	2803	1634	58.3	2043	72.9	2342	83.6
	NEW ORLEANS	2682	1598	59.6	2001	74.6	2292	85.5
	SHREVEPORT	2970	1708	57.5	2160	72.7	2495	84.0
MAINE	PORTLAND	4361	1739	39.9	2331	53.5	2968	68.1
MARYLAND	BALTIMORE	3610	1660	46.0	2202	61.0	2681	74.3
MASSACHUSETTS	BOSTON	3947	1649	41.8	2187	55.4	2742	69.5
	WORCESTER	4278	1662	38.8	2226	52.0	2863	66.9
MICHIGAN	ALPENA	4473	1579	35.3	2161	48.3	2739	61.2
	DETROIT	3995	1446	36.2	1977	49.5	2492	62.4
	FLINT	4193	1522	36.3	2068	49.3	2609	62.2
	GRAND RAPIDS	4174	1545	37.0	2102	50.4	2606	62.4
	HOUGHTON LAKE	4430	1461	33.0	2024	45.7	2596	58.6
	LANSING	4185	1539	36.8	2110	50.4	2640	63.1
	MUSKEGON	4200	1545	36.8	2093	49.8	2585	61.5
	SAULT STE. MARIE	4711	1587	33.7	2171	46.1	2808	59.6
	TRAVERSE CITY	4358	1494	34.3	2040	46.8	2597	59.6
MINNESOTA	DULUTH	4786	1653	34.5	2263	47.3	2928	61.2
	INTERNATIONAL FALLS	4870	1554	31.9	2159	44.3	2798	57.5
	MINNEAPOLIS	4313	1682	39.0	2305	53.4	2893	67.1
	ROCHESTER	4475	1632	36.5	2244	50.1	2832	63.3
MISSISSIPPI	JACKSON	3031	1895	62.5	2208	72.8	2540	83.8
	MERIDIAN	3070	1684	54.9	2182	71.1	2545	82.9
MISSOURI	COLUMBIA	3755	1772	47.2	2346	62.5	2807	74.8
	KANSAS CITY	3757	1801	47.9	2388	63.6	2898	77.1
	SPRINGFIELD	3614	1746	48.3	2310	63.9	2761	76.4
	ST. LOUIS	3585	1681	46.9	2201	61.4	2647	73.8
MONTANA	BILLINGS	4168	1801	43.2	2412	57.9	2931	70.3
	CUT BANK	4502	1824	40.5	2482	55.1	3093	68.7
	GLASGOW	4439	1759	39.6	2401	54.1	2949	66.4
	GREAT FALLS	4397	1764	40.1	2408	54.8	2997	68.2
	HELENA	4386	1772	40.4	2401	54.7	2963	67.6
	KALISPELL	4461	1569	35.2	2145	48.1	2665	59.7
	LEWISTON	4482	1751	39.1	2393	53.4	3006	67.1
	MILES CITY	4299	1844	42.9	2469	57.4	2990	69.6
	MISSOULA	4340	1603	36.9	2186	50.4	2695	62.1
NEBRASKA	GRAND ISLAND	4064	1883	46.3	2534	62.4	3064	75.4
	NORFOLK	4122	1849	44.9	2488	60.4	3018	73.2
	NORTH PLATTE	4105	1924	46.9	2606	63.5	3158	76.9
	SCOTTSBLUFF	4115	1949	47.4	2603	63.3	3135	76.2
NEVADA	ELKO	4237	2085	49.2	2748	64.9	3253	76.8
	ELY	4343	2202	50.7	2950	67.9	3556	81.9
	LAS VEGAS	2761	1935	70.1	2279	82.5	2524	91.4
	RENO	3885	2129	54.8	2726	70.2	3178	81.8
	TONOPAH	3873	2243	57.9	2867	74.0	3295	85.1
	WINNEMUCCA	3992	2093	52.4	2721	68.2	3183	79.7
NEW HAMPSHIRE	CONCORD	4285	1641	38.3	2223	51.9	2810	65.6
NEW JERSEY	ATLANTIC CITY	3758	1700	45.2	2276	60.6	2806	74.7
	NEWARK	3702	1600	43.2	2135	57.7	2638	71.3
NEW MEXICO	ALBUQUERQUE	3551	2255	63.5	2839	79.9	3230	91.0
	TUCUMCARI	3535	2124	60.1	2717	76.9	3130	88.5
NEW YORK	ALBANY	4153	1619	39.0	2179	52.5	2746	66.1
	BINGHAMTON	4244	1519	35.8	2047	48.2	2624	61.8
	BUFFALO	4145	1522	36.7	2048	49.4	2560	61.8
	MASSENA	4403	1583	36.0	2144	48.7	2742	62.3
	NEW YORK CITY	3696	1616	43.7	2141	57.9	2619	70.9

***BEopt* Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters**								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	ROCHESTER	4096	1495	36.5	2018	49.3	2529	61.7
	SYRACUSE	4123	1532	37.2	2066	50.1	2608	63.3
NORTH CAROLINA	ASHEVILLE	3667	1792	48.9	2413	65.8	2951	80.5
	CAPE HATTERAS	3103	1723	55.5	2192	70.6	2543	82.0
	CHARLOTTE	3256	1767	54.3	2302	70.7	2689	82.6
	GREENSBORO	3457	1717	49.7	2272	65.7	2724	78.8
	RALEIGH	3346	1729	51.7	2273	67.9	2702	80.8
	WILMINGTON	3067	1649	53.8	2183	71.2	2598	84.7
NORTH DAKOTA	BISMARCK	4488	1794	40.0	2506	55.8	3186	71.0
	FARGO	4618	1730	37.5	2408	52.1	3105	67.2
	MINOT	4606	1745	37.9	2410	52.3	3009	65.3
OHIO	AKRON	4039	1357	33.6	1887	46.7	2461	60.9
	CLEVELAND	3970	1388	35.0	1935	48.7	2484	62.6
	COLUMBUS	3879	1456	37.5	2013	51.9	2594	66.9
	DAYTON	3923	1497	38.2	2061	52.5	2642	67.3
	MANSFIELD	4115	1521	37.0	2054	49.9	2607	63.4
	TOLEDO	4091	1603	39.2	2181	53.3	2711	66.3
	YOUNGSTOWN	4127	1449	35.1	1969	47.7	2509	60.8
OKLAHOMA	OKLAHOMA CITY	3336	1705	51.1	2274	68.2	2677	80.2
	TULSA	3305	1769	53.5	2285	69.1	2683	81.2
OREGON	ASTORIA	3905	1290	33.0	1769	45.3	2313	59.2
	BURNS	4320	1931	44.7	2595	60.1	3119	72.2
	EUGENE	3867	1490	38.5	2016	52.1	2443	63.2
	MEDFORD	3773	1765	46.8	2297	60.9	2701	71.6
	NORTH BEND	3871	1639	42.3	2178	56.3	2727	70.4
	PENDLETON	3869	1730	44.7	2235	57.8	2654	68.6
	PORTLAND	3740	1408	37.6	1886	50.4	2317	62.0
	REDMOND	4183	1889	45.2	2532	60.5	3018	72.1
	SALEM	3805	1486	39.1	1986	52.2	2423	63.7
PENNSYLVANIA	ALLENTOWN	3901	1587	40.7	2127	54.5	2648	67.9
	BRADFORD	4485	1526	34.0	2072	46.2	2685	59.9
	ERIE	4090	1482	36.2	1983	48.5	2472	60.4
	HARRISBURG	3918	1486	37.9	2027	51.7	2569	65.6
	PHILADELPHIA	3672	1662	45.3	2216	60.3	2698	73.5
	PITTSBURGH	3950	1529	38.7	2061	52.2	2564	64.9
	WILKES-BARRE	4036	1529	37.9	2053	50.9	2586	64.1
	WILLIAMSPORT	3935	1518	38.6	2053	52.2	2582	65.6
RHODE ISLAND	PROVIDENCE	3958	1614	40.8	2163	54.6	2738	69.2
SOUTH CAROLINA	CHARLESTON	2934	1727	58.9	2195	74.8	2519	85.9
	COLUMBIA	3088	1708	55.3	2208	71.5	2560	82.9
SOUTH DAKOTA	PIERRE	4188	1793	42.8	2426	57.9	2961	70.7
	RAPID CITY	4237	1929	45.5	2580	60.9	3146	74.3
	SIOUX FALLS	4296	1762	41.0	2404	56.0	2984	69.5
TENNESSEE	CHATTANOOGA	3285	1650	50.2	2172	66.1	2594	79.0
	KNOXVILLE	3454	1671	48.4	2204	63.8	2659	77.0
	MEMPHIS	3120	1691	54.2	2145	68.8	2495	80.0
	NASHVILLE	3331	1687	50.6	2190	65.7	2599	78.0
TEXAS	ABILENE	3114	1934	62.1	2420	77.7	2733	87.8
	AMARILLO	3534	2061	58.3	2677	75.7	3090	87.4
	AUSTIN	2674	1568	58.6	1949	72.9	2240	83.8
	BROWNSVILLE	2391	1511	63.2	1830	76.5	2042	85.4
	CORPUS CHRISTI	2517	1527	60.7	1872	74.4	2116	84.1
	EL PASO	2999	2158	72.0	2582	86.1	2795	93.2
	FORT WORTH	3029	1722	56.9	2206	72.8	2540	83.9
	HOUSTON	2692	1576	58.5	1986	73.8	2290	85.1
	LUBBOCK	3328	1997	60.0	2578	77.5	2954	88.8
	LUFKIN	2874	1661	57.8	2090	72.7	2401	83.5
	MIDLAND	3071	2004	65.3	2511	81.8	2783	90.6
	PORT ARTHUR	2700	1594	59.0	1974	73.1	2253	83.4
	SAN ANGELO	3025	1927	63.7	2416	79.9	2683	88.7

***BEopt* Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters**								
		E	**E32ICS**		**E40FPCL**		**E64FPCL**	
State	**City**	(kWh)	AS (kWh)	FS (%)	AS (kWh)	FS (%)	AS (kWh)	FS (%)
	SAN ANTONIO	2688	1708	63.5	2089	77.7	2340	87.1
	VICTORIA	2646	1588	60.0	1971	74.5	2230	84.3
	WACO	2891	1726	59.7	2138	74.0	2452	84.8
	WICHITA FALLS	3082	1840	59.7	2309	74.9	2636	85.5
UTAH	CEDAR CITY	3919	2209	56.4	2878	73.4	3327	84.9
	SALT LAKE CITY	3783	1847	48.8	2398	63.4	2812	74.3
VERMONT	BURLINGTON	4296	1552	36.1	2090	48.6	2666	62.1
VIRGINIA	LYNCHBURG	3530	1780	50.4	2334	66.1	2782	78.8
	NORFOLK	3304	1677	50.8	2196	66.5	2605	78.8
	RICHMOND	3424	1717	50.1	2261	66.0	2722	79.5
	ROANOKE	3565	1715	48.1	2277	63.9	2756	77.3
	WASHINGTON D.C.	3399	1424	41.9	1951	57.4	2435	71.6
WASHINGTON	OLYMPIA	3985	1296	32.5	1778	44.6	2265	56.8
	QUILLAYUTE	4072	1239	30.4	1695	41.6	2214	54.4
	SEATTLE	3791	1348	35.6	1803	47.6	2260	59.6
	SPOKANE	4190	1649	39.4	2186	52.2	2651	63.3
	YAKIMA	4028	1730	42.9	2305	57.2	2752	68.3
WEST VIRGINIA	CHARLESTON	3676	1596	43.4	2134	58.1	2621	71.3
	HUNTINGTON	3649	1559	42.7	2088	57.2	2578	70.6
WISCONSIN	EAU CLAIRE	4464	1658	37.1	2264	50.7	2876	64.4
	GREEN BAY	4360	1638	37.6	2224	51.0	2820	64.7
	LA CROSSE	4256	1670	39.2	2270	53.3	2839	66.7
	MADISON	4314	1661	38.5	2255	52.3	2802	65.0
	MILWAUKEE	4267	1654	38.8	2218	52.0	2792	65.4
WYOMING	CASPER	4313	1983	46.0	2660	61.7	3223	74.7
	CHEYENNE	4340	1993	45.9	2696	62.1	3345	77.1
	LANDER	4334	2091	48.2	2810	64.8	3407	78.6

Table D2. *BEopt* Summary of Auxiliary Natural Gas Simulations Results

***BEopt* Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters**								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
ALABAMA	BIRMINGHAM	176	74	42.0	106	60.2	134	76.1
	MOBILE	164	72	43.9	104	63.4	130	79.3
	MONTGOMERY	171	76	44.4	109	63.7	136	79.5
ARIZONA	FLAGSTAFF	225	96	42.7	138	61.3	178	79.1
	PHOENIX	139	87	62.6	115	82.7	128	92.1
	PRESCOTT	195	95	48.7	136	69.7	166	85.1
	TUCSON	158	92	58.2	130	82.3	147	93.0
ARKANSAS	FORT SMITH	184	76	41.3	111	60.3	137	74.5
	LITTLE ROCK	181	67	37.0	99	54.7	125	69.1
CALIFORNIA	ARCATA	210	67	31.9	98	46.7	129	61.4
	BAKERSFIELD	168	83	49.4	118	70.2	135	80.4
	FRESNO	171	82	48.0	117	68.4	134	78.4
	LONG BEACH	173	84	48.6	120	69.4	147	85.0
	LOS ANGELES	177	86	48.6	120	67.8	150	84.7
	SACRAMENTO	182	82	45.1	120	65.9	139	76.4
	SAN DIEGO	172	89	51.7	124	72.1	152	88.4
	SAN FRANCISCO	193	82	42.5	117	60.6	149	77.2
COLORADO	ALAMOSA	239	103	43.1	148	61.9	191	79.9
	COLORADO SPRINGS	216	88	40.7	128	59.3	163	75.5
	EAGLE	234	86	36.8	127	54.3	164	70.1
	GRAND JUNCTION	203	89	43.8	128	63.1	156	76.8
	PUEBLO	205	92	44.9	134	65.4	165	80.5
CONNECTICUT	BRIDGEPORT	208	68	32.7	99	47.6	129	62.0
	HARTFORD	212	65	30.7	97	45.8	126	59.4
DELAWARE	WILMINGTON	202	70	34.7	102	50.5	132	65.3
FLORIDA	DAYTONA BEACH	153	76	49.7	110	71.9	133	86.9
	JACKSONVILLE	160	71	44.4	104	65.0	130	81.3
	MIAMI	136	71	52.2	102	75.0	122	89.7
	TALLAHASSEE	163	72	44.2	107	65.6	132	81.0
	TAMPA	148	77	52.0	111	75.0	133	89.9
	WEST PALM BEACH	141	74	52.5	105	74.5	127	90.1
GEORGIA	ATHENS	178	74	41.6	108	60.7	137	77.0
	ATLANTA	178	75	42.1	110	61.8	137	77.0
	AUGUSTA	174	76	43.7	111	63.8	138	79.3
	COLUMBUS	168	73	43.5	106	63.1	132	78.6
	MACON	172	74	43.0	109	63.4	134	77.9
	SAVANNAH	165	74	44.8	108	65.5	133	80.6
IDAHO	BOISE	207	77	37.2	114	55.1	140	67.6
	POCATELLO	222	80	36.0	118	53.2	149	67.1
ILLINOIS	CHICAGO	214	67	31.3	98	45.8	127	59.3
	MOLINE	213	70	32.9	104	48.8	134	62.9
	PEORIA	212	71	33.5	104	49.1	134	63.2
	ROCKFORD	221	68	30.8	101	45.7	131	59.3
	SPRINGFIELD	204	72	35.3	106	52.0	136	66.7
INDIANA	EVANSVILLE	194	71	36.6	104	53.6	132	68.0
	FORT WAYNE	215	65	30.2	97	45.1	126	58.6
	INDIANAPOLIS	208	69	33.2	102	49.0	130	62.5
	SOUTH BEND	210	63	30.0	95	45.2	123	58.6
IOWA	DES MOINES	212	74	34.9	109	51.4	139	65.6
	MASON CITY	228	70	30.7	104	45.6	135	59.2
	SIOUX CITY	217	74	34.1	109	50.2	140	64.5
	WATERLOO	221	70	31.7	104	47.1	136	61.5
KANSAS	DODGE CITY	200	86	43.0	125	62.5	156	78.0
	GOODLAND	211	88	41.7	128	60.7	161	76.3
	TOPEKA	199	75	37.7	110	55.3	139	69.8
	WICHITA	193	80	41.5	117	60.6	145	75.1
KENTUCKY	LEXINGTON	200	67	33.5	99	49.5	128	64.0

BEopt Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
	LOUISVILLE	190	59	31.1	89	46.8	116	61.1
LOUISIANA	BATON ROUGE	163	68	41.7	99	60.7	123	75.5
	LAKE CHARLES	163	71	43.6	103	63.2	127	77.9
	NEW ORLEANS	158	70	44.3	101	63.9	125	79.1
	SHREVEPORT	170	74	43.5	108	63.5	133	78.2
MAINE	PORTLAND	228	72	31.6	104	45.6	137	60.1
MARYLAND	BALTIMORE	196	69	35.2	101	51.5	130	66.3
MASSACHUSETTS	BOSTON	211	69	32.7	100	47.4	130	61.6
	WORCESTER	225	69	30.7	100	44.4	132	58.7
MICHIGAN	ALPENA	233	65	27.9	97	41.6	127	54.5
	DETROIT	213	60	28.2	90	42.3	118	55.4
	FLINT	221	62	28.1	93	42.1	122	55.2
	GRAND RAPIDS	220	63	28.6	95	43.2	123	55.9
	HOUGHTON LAKE	231	60	26.0	91	39.4	119	51.5
	LANSING	221	64	29.0	96	43.4	125	56.6
	MUSKEGON	221	63	28.5	94	42.5	123	55.7
	SAULT STE. MARIE	243	65	26.7	97	39.9	128	52.7
	TRAVERSE CITY	228	61	26.8	92	40.4	120	52.6
MINNESOTA	DULUTH	246	67	27.2	101	41.1	132	53.7
	INTERNATIONAL FALLS	250	63	25.2	97	38.8	127	50.8
	MINNEAPOLIS	226	69	30.5	103	45.6	135	59.7
	ROCHESTER	233	67	28.8	100	42.9	132	56.7
MISSISSIPPI	JACKSON	172	75	43.6	108	62.8	134	77.9
	MERIDIAN	174	72	41.4	105	60.3	132	75.9
MISSOURI	COLUMBIA	203	75	36.9	109	53.7	139	68.5
	KANSAS CITY	203	76	37.4	112	55.2	142	70.0
	SPRINGFIELD	197	74	37.6	108	54.8	137	69.5
	ST. LOUIS	195	71	36.4	103	52.8	131	67.2
MONTANA	BILLINGS	220	75	34.1	110	50.0	141	64.1
	CUT BANK	234	75	32.1	111	47.4	144	61.5
	GLASGOW	231	72	31.2	108	46.8	139	60.2
	GREAT FALLS	230	73	31.7	109	47.4	141	61.3
	HELENA	229	73	31.9	108	47.2	140	61.1
	KALISPELL	232	64	27.6	97	41.8	125	53.9
	LEWISTON	233	72	30.9	107	45.9	140	60.1
	MILES CITY	225	76	33.8	112	49.8	143	63.6
	MISSOULA	227	66	29.1	99	43.6	127	55.9
NEBRASKA	GRAND ISLAND	215	78	36.3	116	54.0	148	68.8
	NORFOLK	218	77	35.3	114	52.3	145	66.5
	NORTH PLATTE	217	80	36.9	119	54.8	152	70.0
	SCOTTSBLUFF	218	82	37.6	120	55.0	152	69.7
NEVADA	ELKO	223	87	39.0	127	57.0	159	71.3
	ELY	227	92	40.5	133	58.6	170	74.9
	LAS VEGAS	161	92	57.1	125	77.6	143	88.8
	RENO	208	90	43.3	131	63.0	159	76.4
	TONOPAH	207	95	45.9	137	66.2	166	80.2
	WINNEMUCCA	212	88	41.5	128	60.4	157	74.1
NEW HAMPSHIRE	CONCORD	225	68	30.2	100	44.4	131	58.2
NEW JERSEY	ATLANTIC CITY	203	71	35.0	104	51.2	135	66.5
	NEWARK	200	67	33.5	98	49.0	126	63.0
NEW MEXICO	ALBUQUERQUE	194	97	50.0	138	71.1	167	86.1
	TUCUMCARI	193	91	47.2	130	67.4	160	82.9
NEW YORK	ALBANY	219	66	30.1	98	44.7	128	58.4
	BINGHAMTON	223	62	27.8	92	41.3	120	53.8
	BUFFALO	219	63	28.8	93	42.5	121	55.3
	MASSENA	230	65	28.3	96	41.7	126	54.8
	NEW YORK CITY	200	67	33.5	99	49.5	127	63.5
	ROCHESTER	217	62	28.6	92	42.4	119	54.8
	SYRACUSE	218	63	28.9	93	42.7	122	56.0

BEopt Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
NORTH CAROLINA	ASHEVILLE	199	75	37.7	110	55.3	143	71.9
	CAPE HATTERAS	175	73	41.7	105	60.0	132	75.4
	CHARLOTTE	182	75	41.2	109	59.9	139	76.4
	GREENSBORO	190	72	37.9	106	55.8	135	71.1
	RALEIGH	185	73	39.5	106	57.3	136	73.5
	WILMINGTON	173	69	39.9	101	58.4	131	75.7
NORTH DAKOTA	BISMARCK	233	73	31.3	111	47.6	147	63.1
	FARGO	239	71	29.7	107	44.8	142	59.4
	MINOT	238	71	29.8	107	45.0	140	58.8
OHIO	AKRON	214	55	25.7	85	39.7	112	52.3
	CLEVELAND	212	57	26.9	88	41.5	116	54.7
	COLUMBUS	208	60	28.8	91	43.8	120	57.7
	DAYTON	210	62	29.5	93	44.3	123	58.6
	MANSFIELD	218	63	28.9	93	42.7	122	56.0
	TOLEDO	217	66	30.4	99	45.6	129	59.4
	YOUNGSTOWN	218	59	27.1	89	40.8	116	53.2
OKLAHOMA	OKLAHOMA CITY	185	72	38.9	107	57.8	137	74.1
	TULSA	184	76	41.3	111	60.3	138	75.0
OREGON	ASTORIA	209	53	25.4	80	38.3	106	50.7
	BURNS	226	80	35.4	118	52.2	150	66.4
	EUGENE	207	62	30.0	93	44.9	119	57.5
	MEDFORD	203	74	36.5	109	53.7	135	66.5
	NORTH BEND	207	67	32.4	98	47.3	128	61.8
	PENDLETON	207	72	34.8	105	50.7	131	63.3
	PORTLAND	202	58	28.7	87	43.1	111	55.0
	REDMOND	221	79	35.7	116	52.5	147	66.5
	SALEM	204	61	29.9	92	45.1	117	57.4
PENNSYLVANIA	ALLENTOWN	209	66	31.6	97	46.4	126	60.3
	BRADFORD	233	62	26.6	92	39.5	122	52.4
	ERIE	217	61	28.1	91	41.9	117	53.9
	HARRISBURG	209	61	29.2	92	44.0	120	57.4
	PHILADELPHIA	199	70	35.2	102	51.3	131	65.8
	PITTSBURGH	211	63	29.9	94	44.5	122	57.8
	WILKES-BARRE	214	63	29.4	93	43.5	121	56.5
	WILLIAMSPORT	210	62	29.5	93	44.3	121	57.6
RHODE ISLAND	PROVIDENCE	211	67	31.8	98	46.4	128	60.7
SOUTH CAROLINA	CHARLESTON	168	74	44.0	108	64.3	134	79.8
	COLUMBIA	175	73	41.7	107	61.1	134	76.6
SOUTH DAKOTA	PIERRE	221	75	33.9	111	50.2	142	64.3
	RAPID CITY	223	81	36.3	118	52.9	150	67.3
	SIOUX FALLS	225	73	32.4	108	48.0	140	62.2
TENNESSEE	CHATTANOOGA	183	70	38.3	103	56.3	131	71.6
	KNOXVILLE	190	70	36.8	103	54.2	132	69.5
	MEMPHIS	176	73	41.5	106	60.2	131	74.4
	NASHVILLE	185	72	38.9	104	56.2	132	71.4
TEXAS	ABILENE	176	85	48.3	122	69.3	147	83.5
	AMARILLO	193	87	45.1	128	66.3	158	81.9
	AUSTIN	157	69	43.9	101	64.3	122	77.7
	BROWNSVILLE	145	66	45.5	97	66.9	118	81.4
	CORPUS CHRISTI	151	67	44.4	98	64.9	119	78.8
	EL PASO	171	96	56.1	135	78.9	156	91.2
	FORT WORTH	172	74	43.0	109	63.4	136	79.1
	HOUSTON	158	68	43.0	100	63.3	123	77.8
	LUBBOCK	185	86	46.5	126	68.1	154	83.2
	LUFKIN	166	72	43.4	105	63.3	129	77.7
	MIDLAND	174	87	50.0	127	73.0	151	86.8
	PORT ARTHUR	158	69	43.7	100	63.3	123	77.8
	SAN ANGELO	172	84	48.8	122	70.9	146	84.9

***BEopt* Simulated annual energy requirements for standard water heaters with absolute and fractional savings from the addition of solar water heaters**								
		G	**G32ICS**		**G40FPCL**		**G64FPCL**	
State	**City**	Therms	AS (Therms)	FS (%)	AS (Therms)	FS (%)	AS (Therms)	FS (%)
	SAN ANTONIO	158	76	48.1	109	69.0	131	82.9
	VICTORIA	156	69	44.2	100	64.1	121	77.6
	WACO	166	76	45.8	110	66.3	132	79.5
	WICHITA FALLS	174	80	46.0	116	66.7	140	80.5
UTAH	CEDAR CITY	209	93	44.5	135	64.6	167	79.9
	SALT LAKE CITY	204	78	38.2	115	56.4	142	69.6
VERMONT	BURLINGTON	225	63	28.0	94	41.8	123	54.7
VIRGINIA	LYNCHBURG	193	75	38.9	109	56.5	139	72.0
	NORFOLK	184	71	38.6	103	56.0	132	71.7
	RICHMOND	189	73	38.6	106	56.1	135	71.4
	ROANOKE	195	72	36.9	106	54.4	136	69.7
	WASHINGTON D.C.	188	60	31.9	91	48.4	118	62.8
WASHINGTON	OLYMPIA	212	53	25.0	81	38.2	105	49.5
	QUILLAYUTE	216	50	23.1	77	35.6	101	46.8
	SEATTLE	204	55	27.0	83	40.7	107	52.5
	SPOKANE	221	68	30.8	101	45.7	128	57.9
	YAKIMA	214	72	33.6	107	50.0	135	63.1
WEST VIRGINIA	CHARLESTON	199	66	33.2	98	49.2	126	63.3
	HUNTINGTON	198	65	32.8	96	48.5	124	62.6
WISCONSIN	EAU CLAIRE	232	68	29.3	101	43.5	132	56.9
	GREEN BAY	228	67	29.4	100	43.9	130	57.0
	LA CROSSE	224	69	30.8	103	46.0	133	59.4
	MADISON	226	68	30.1	102	45.1	132	58.4
	MILWAUKEE	224	68	30.4	99	44.2	130	58.0
WYOMING	CASPER	226	82	36.3	120	53.1	154	68.1
	CHEYENNE	227	83	36.6	120	52.9	157	69.2
	LANDER	227	87	38.3	127	55.9	163	71.8

Appendix E: *BEopt* Auxiliary Electric Water Heaters Contour Plots

Figure E1. Annual energy consumption in kWh for a standard storage electric water heater

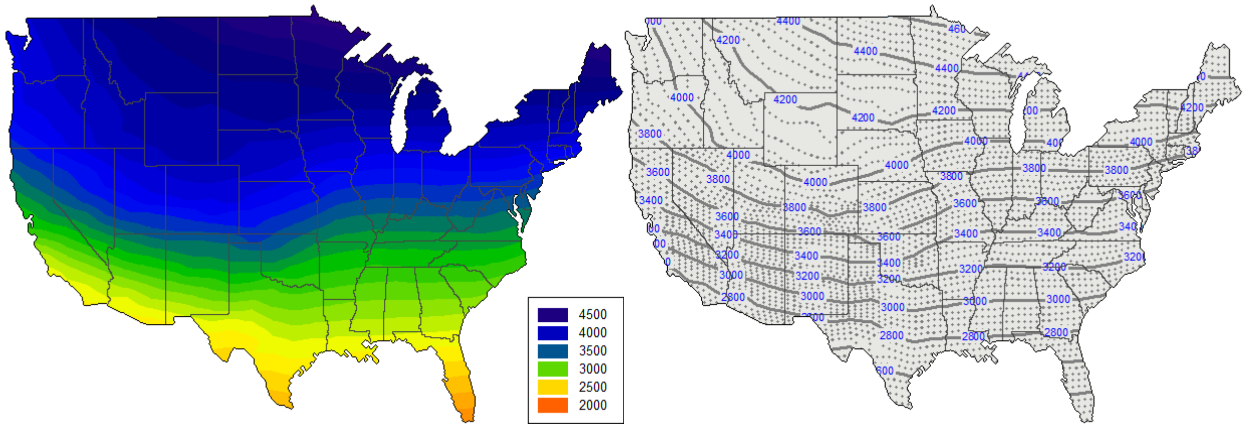


Figure E2. Annual absolute energy savings in kWh for E32ICS

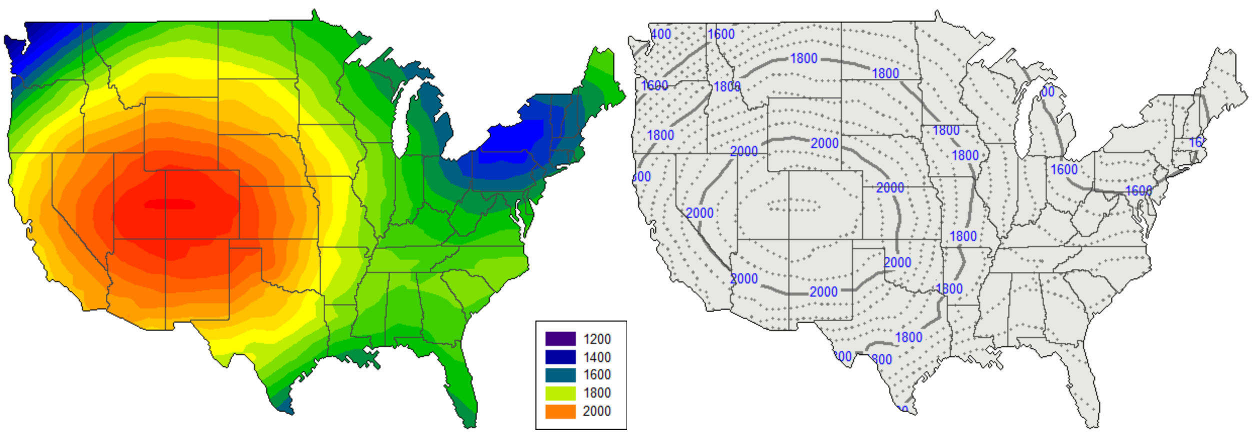


Figure E3. Annual fractional energy savings (%) for E32ICS

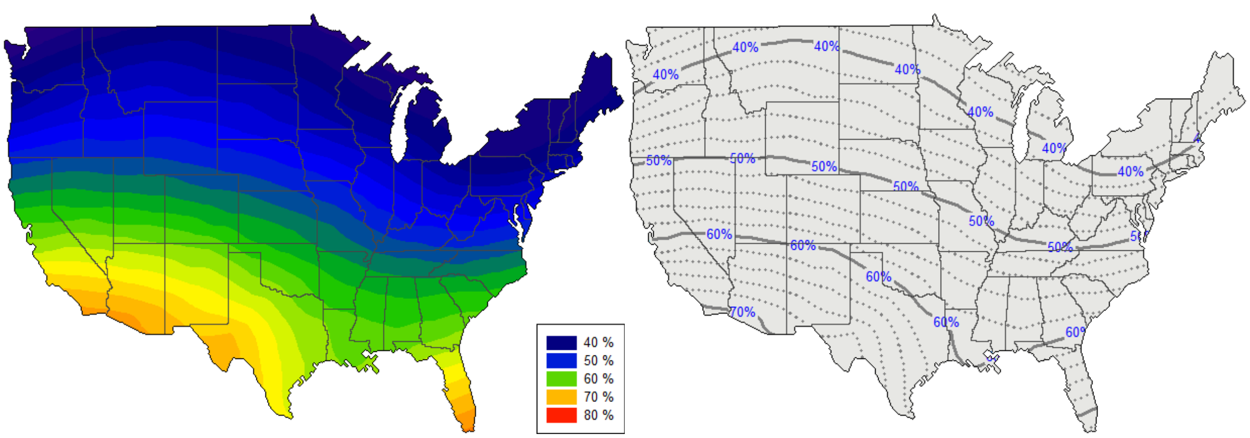


Figure E4. Annual absolute energy savings in kWh for E40FPCL

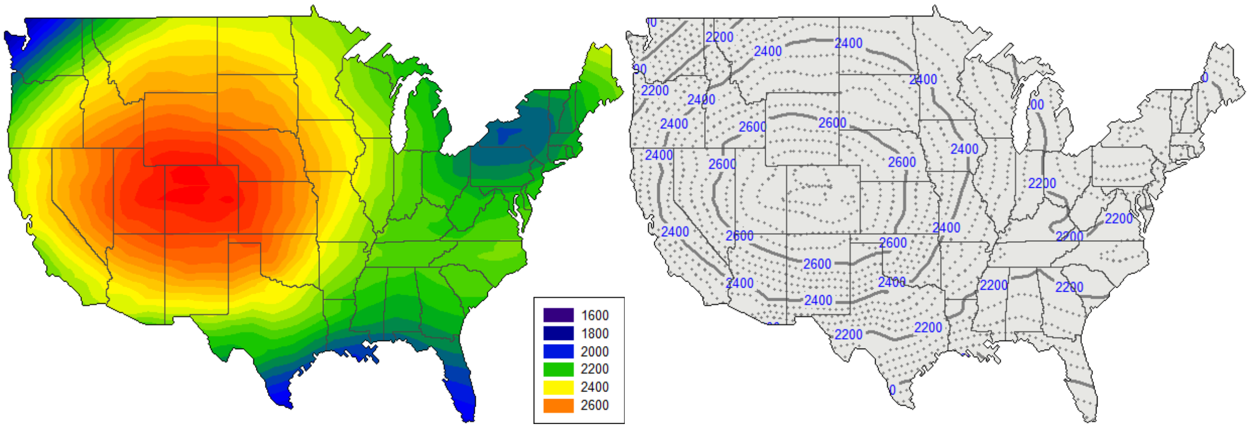


Figure E5. Annual fractional energy savings (%) for E40FPCL

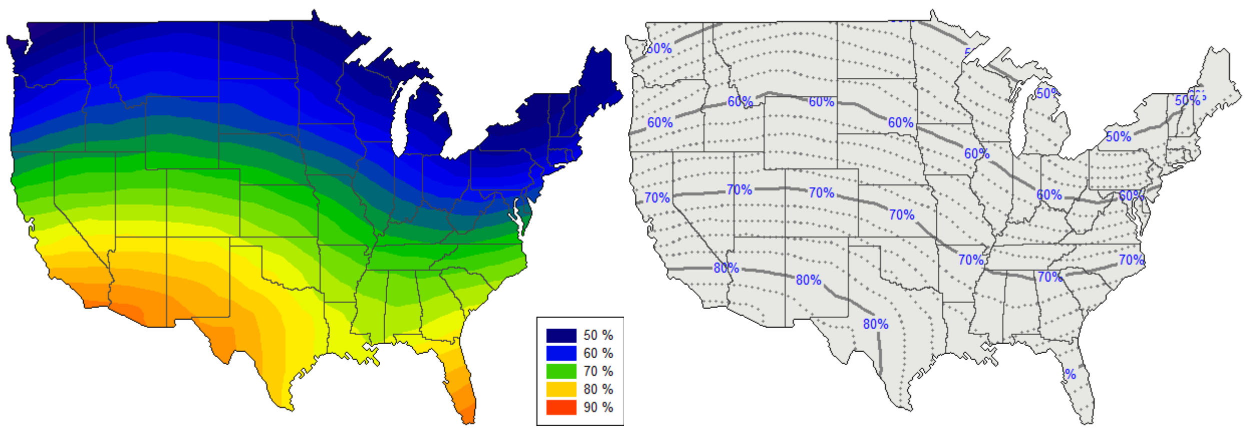


Figure E6. Annual absolute energy savings in kWh for E64FPCL

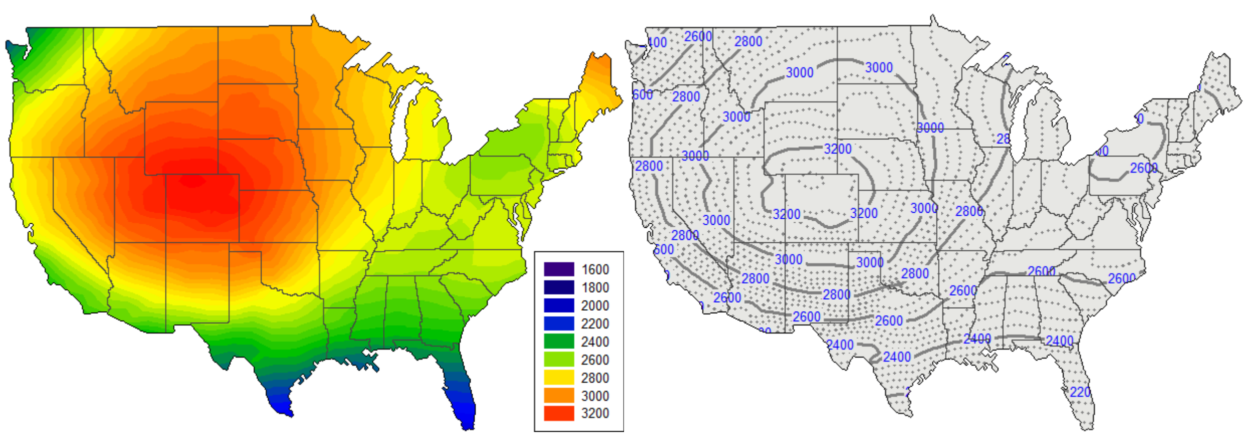
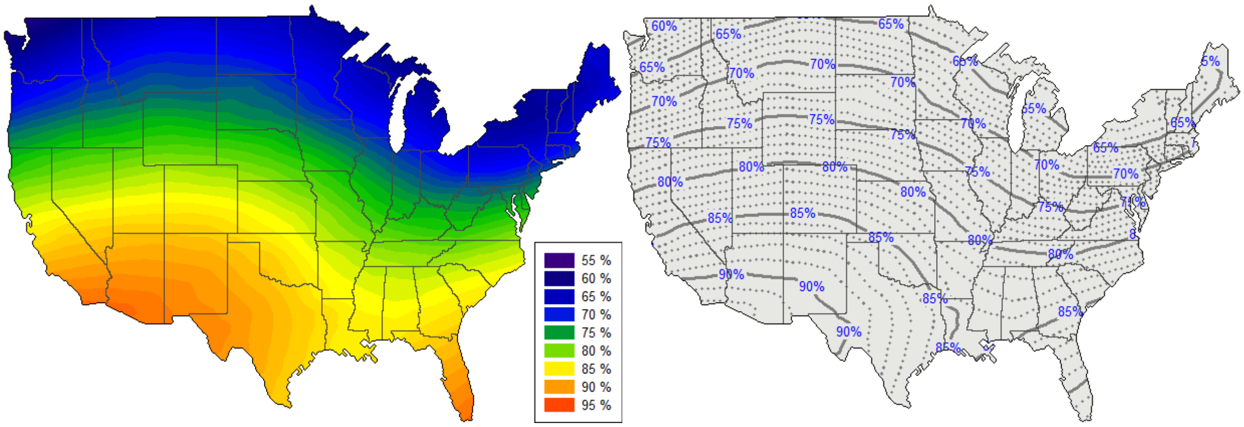


Figure E7. Annual fractional energy savings (%) for E64FPCL



Appendix F: *EGUSA* Auxiliary Electric Water Heaters Contour Plots for California

Figure F1. Annual energy consumption in kWh for a standard storage electric water heater

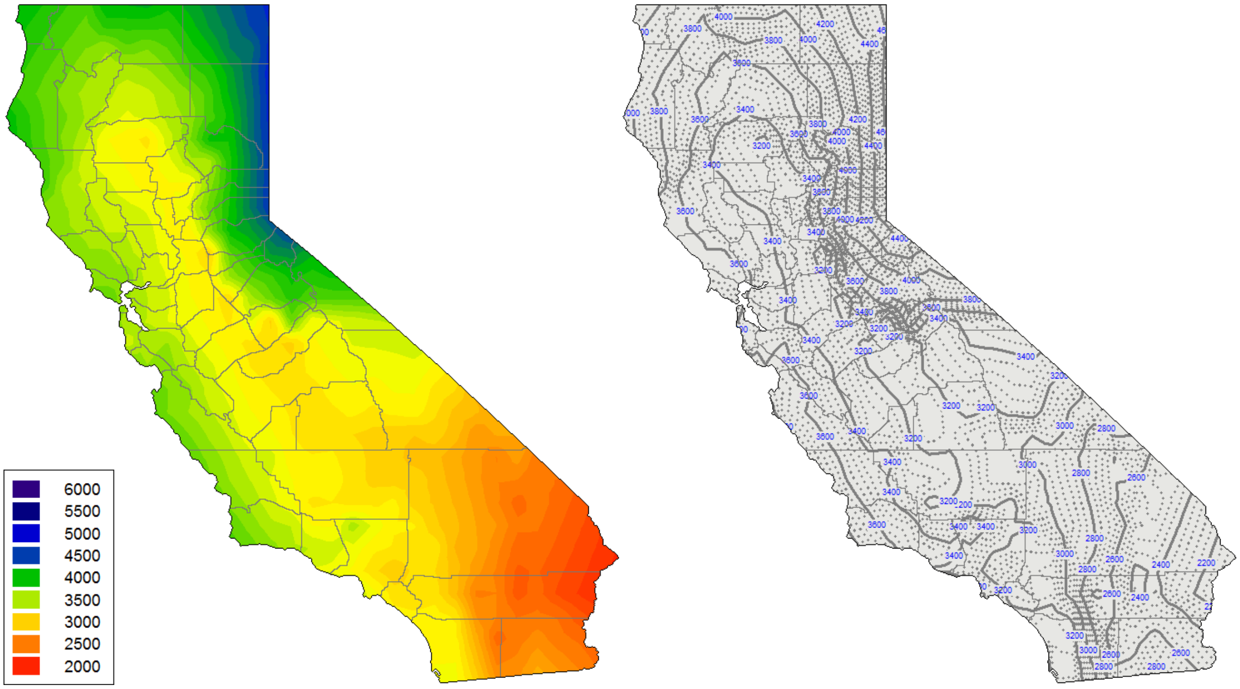


Figure F2. Annual absolute energy savings in kWh for E32ICS

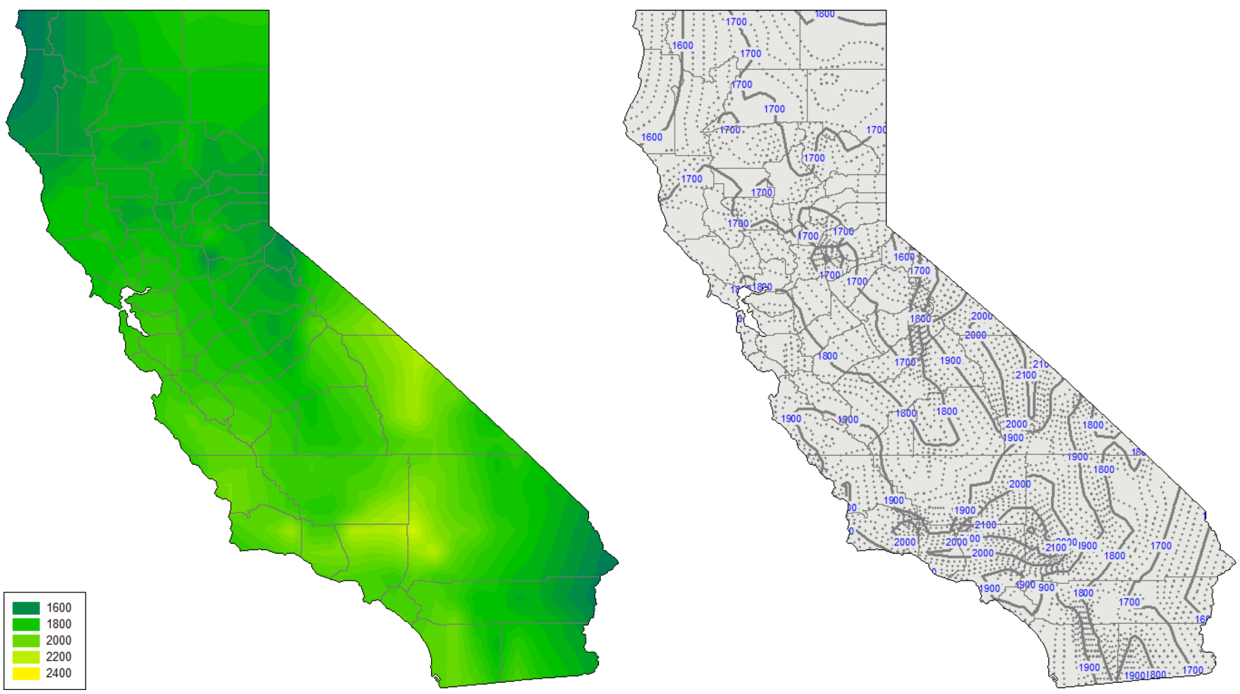


Figure F3. Annual fractional energy savings (%) for E32ICS

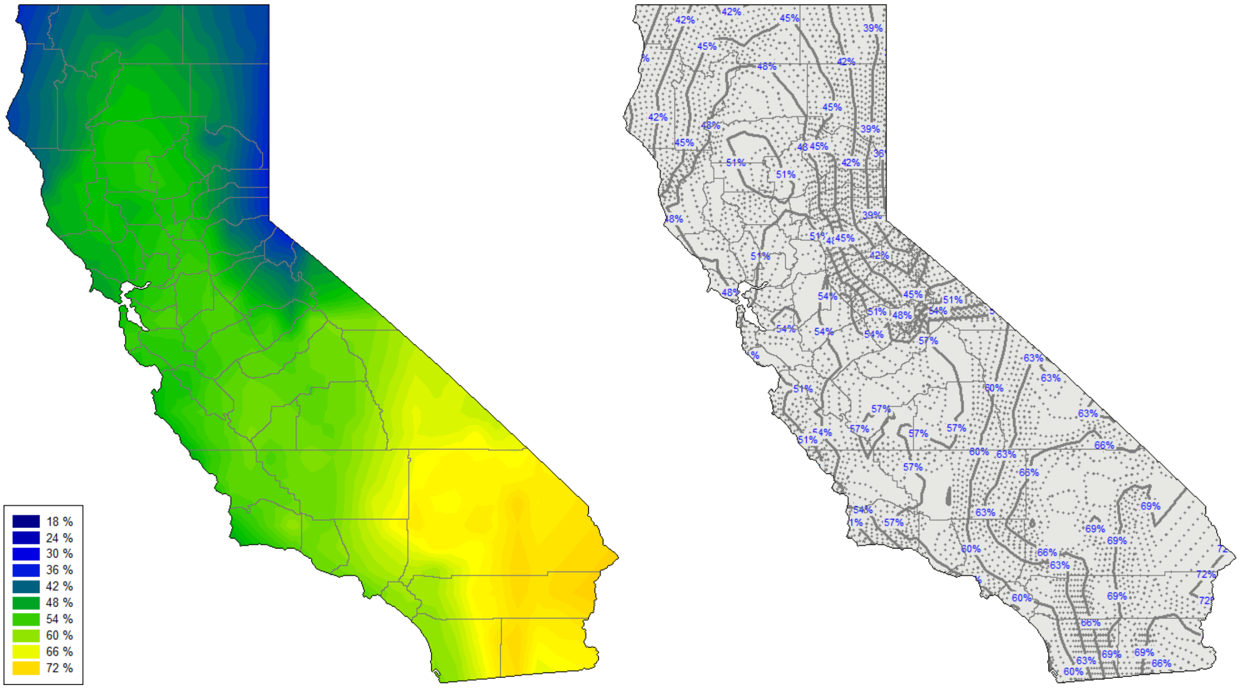


Figure F4. Annual absolute energy savings in kWh for E40FPCL

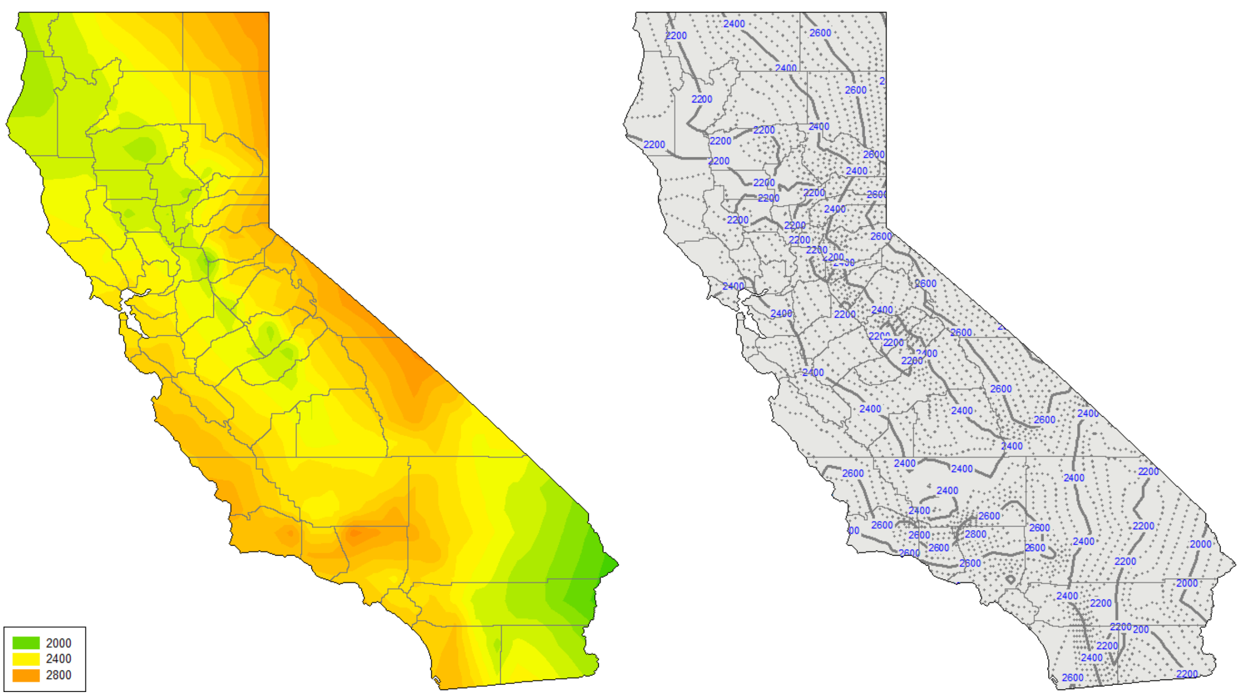


Figure F5. Annual fractional energy savings (%) for E40FPCL

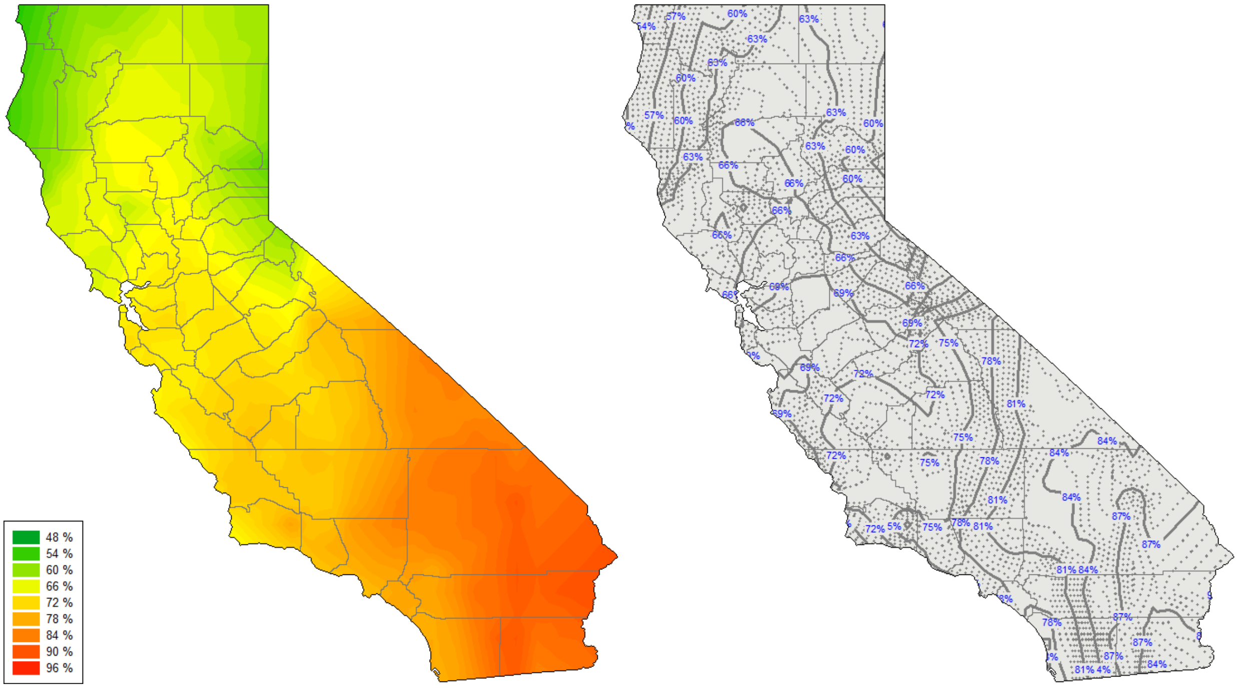


Figure F6. Annual absolute energy savings in kWh for E64FPCL

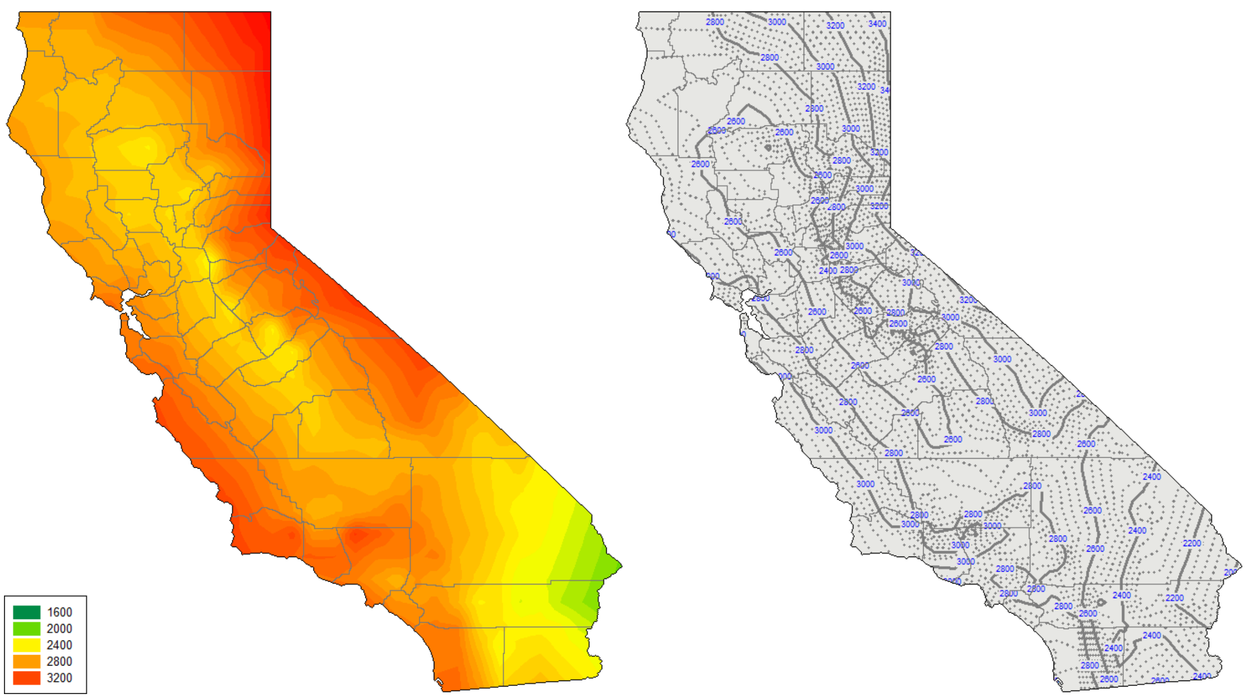
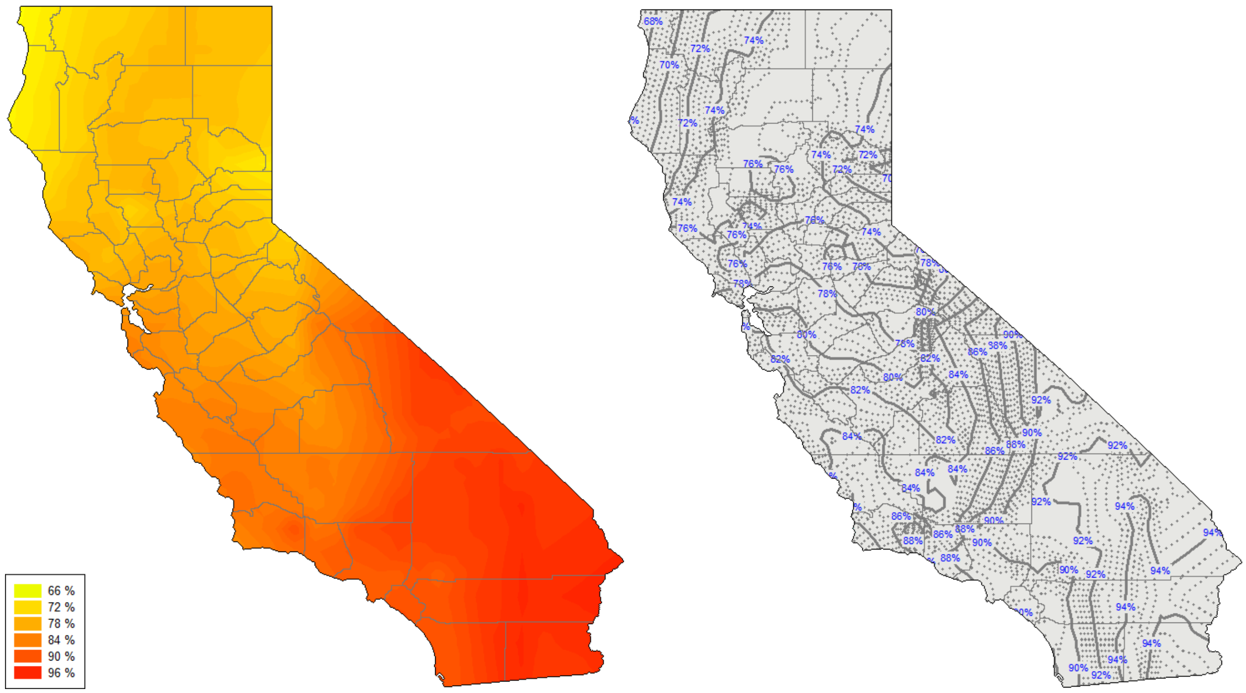


Figure F7. Annual fractional energy savings (%) for E64FPCL



Appendix G: *EGUSA* Auxiliary Natural Gas Water Heaters Contour Plots for California

Figure G1. Annual energy consumption in therms for a standard storage natural gas water heater

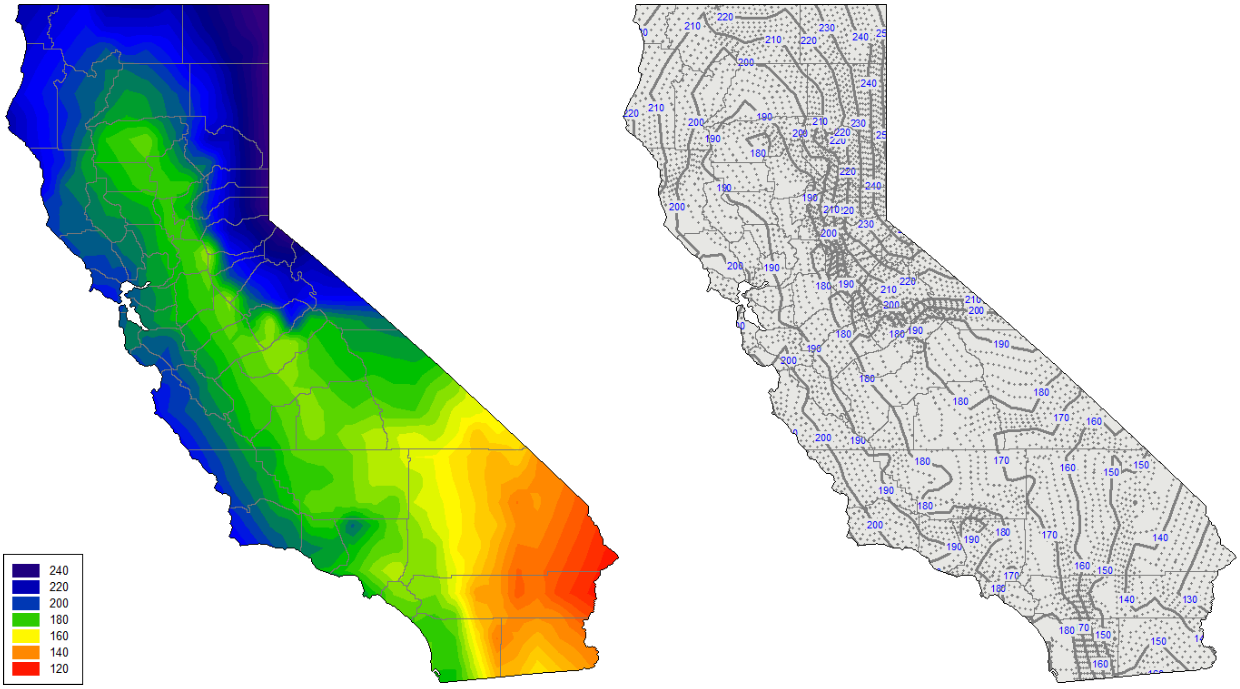


Figure G2. Annual absolute energy savings in therms for G32ICS

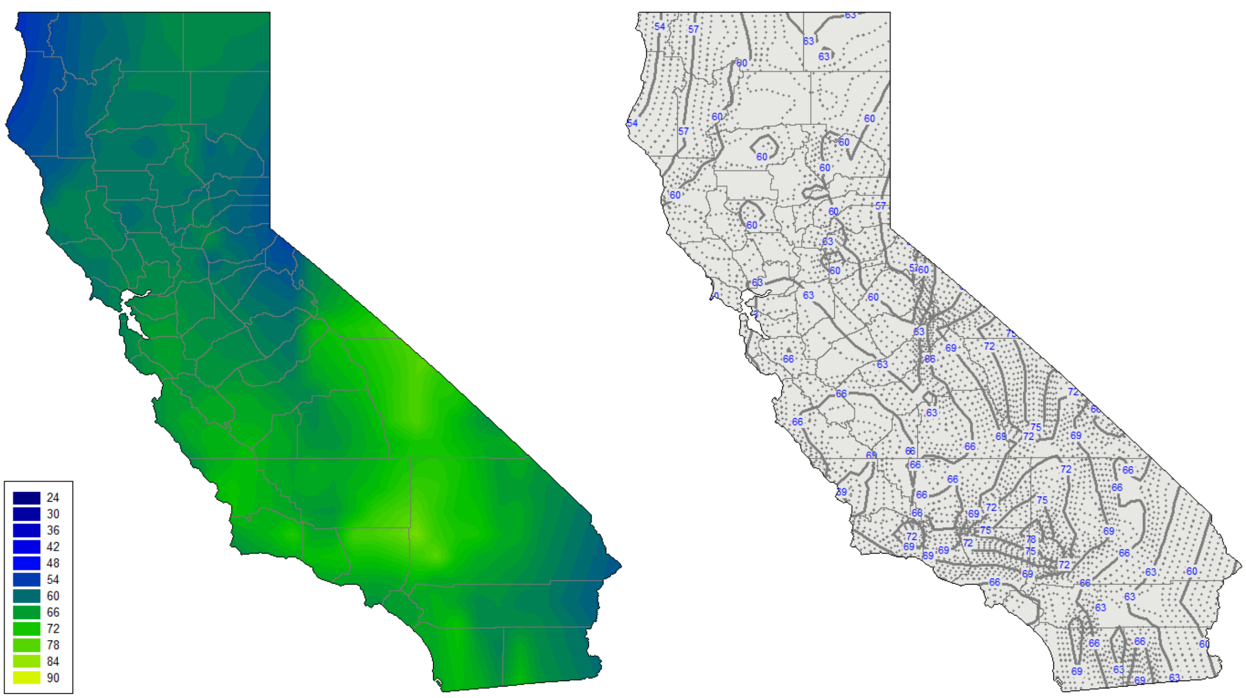


Figure G3. Annual fractional energy savings (%) for G32ICS

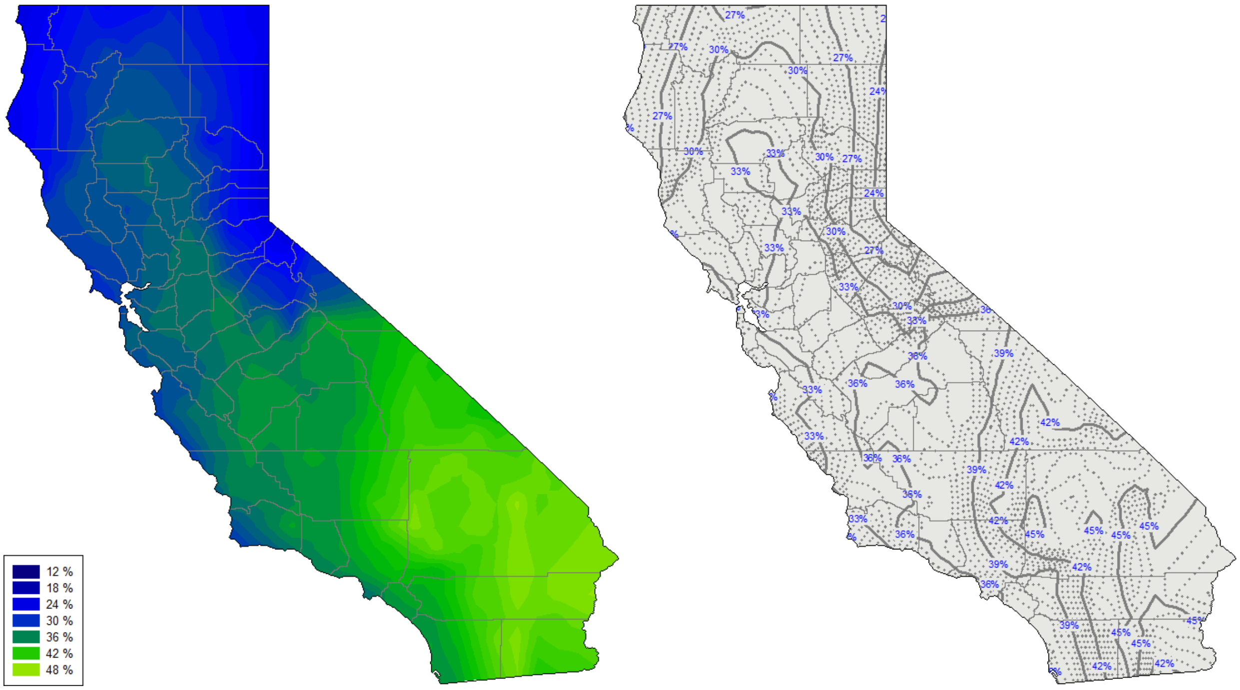


Figure G4. Annual absolute energy savings in therms for G40FPCL

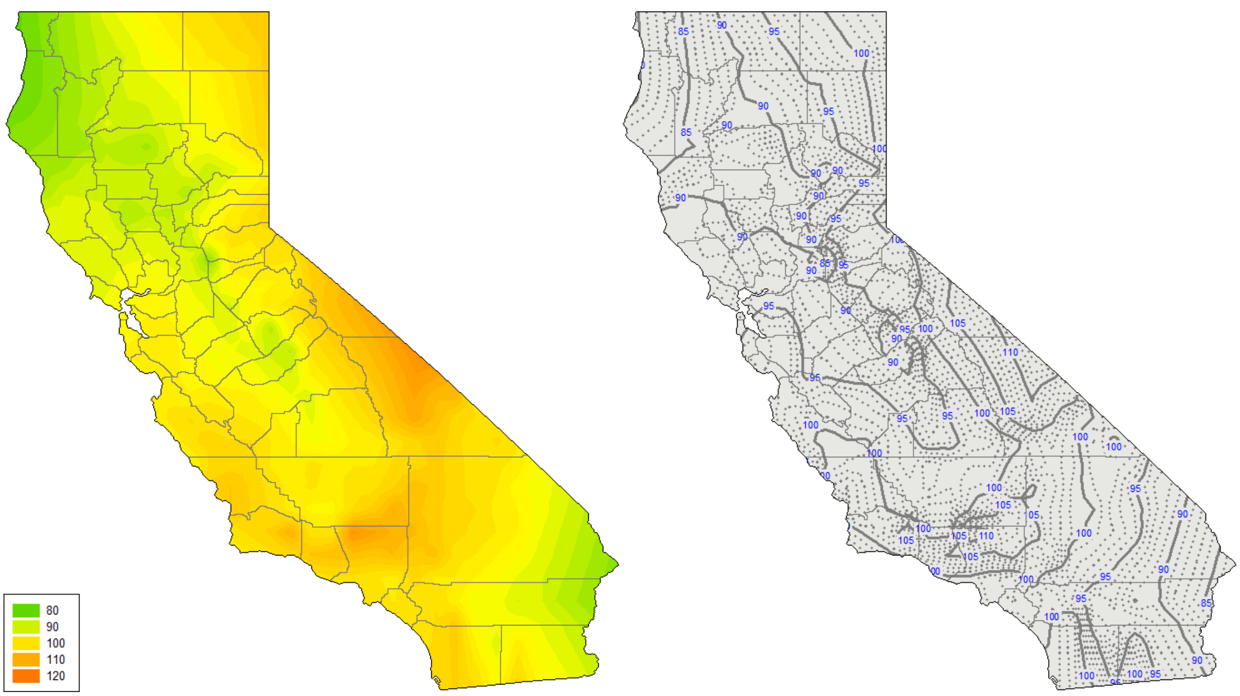


Figure G5. Annual fractional energy savings (%) for G40FPCL

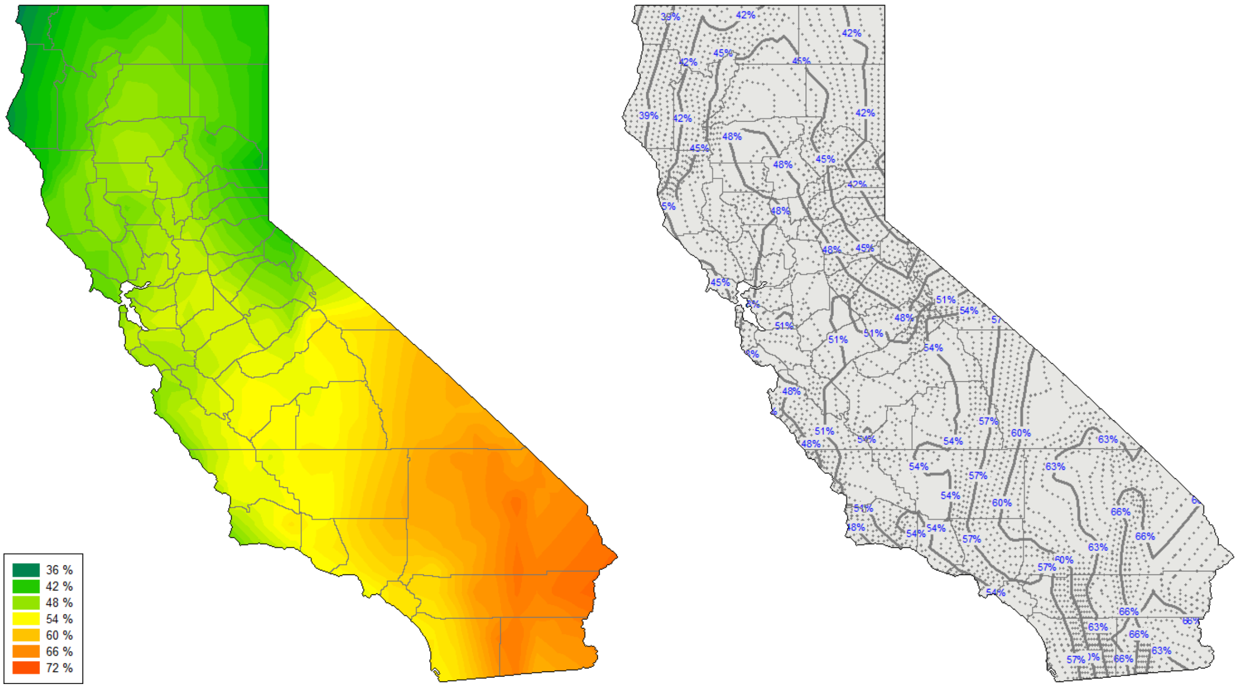


Figure G6. Annual absolute energy savings in therms for G64FPCL

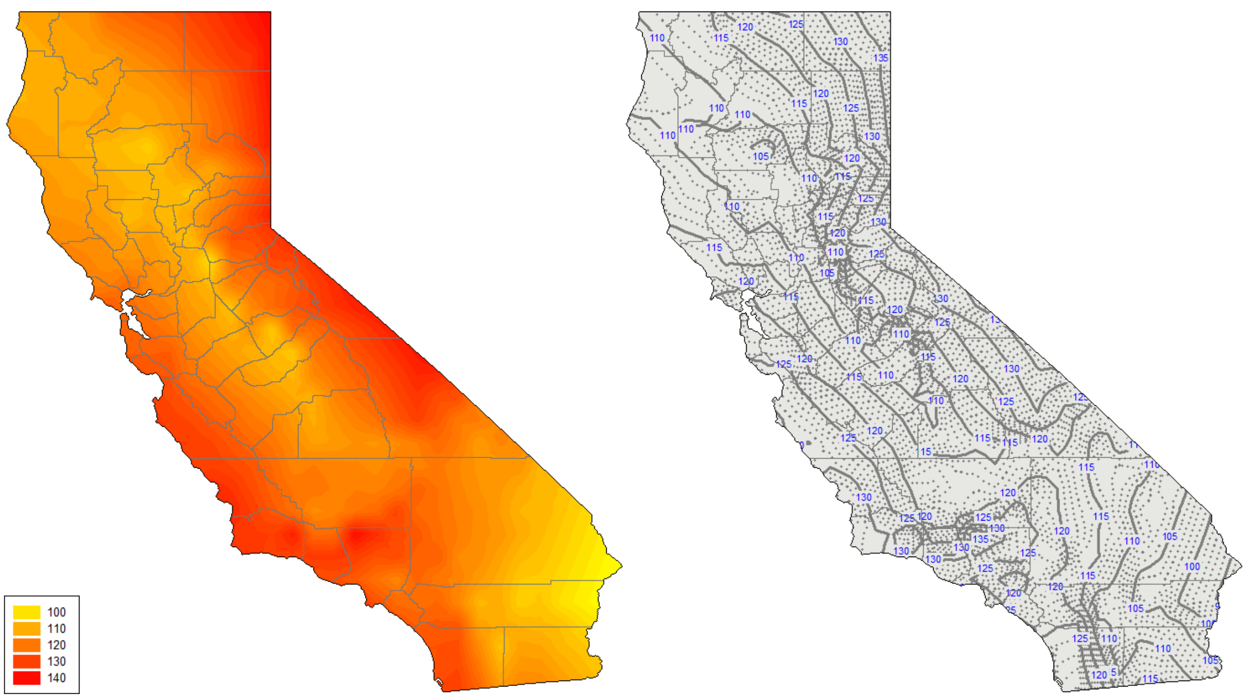
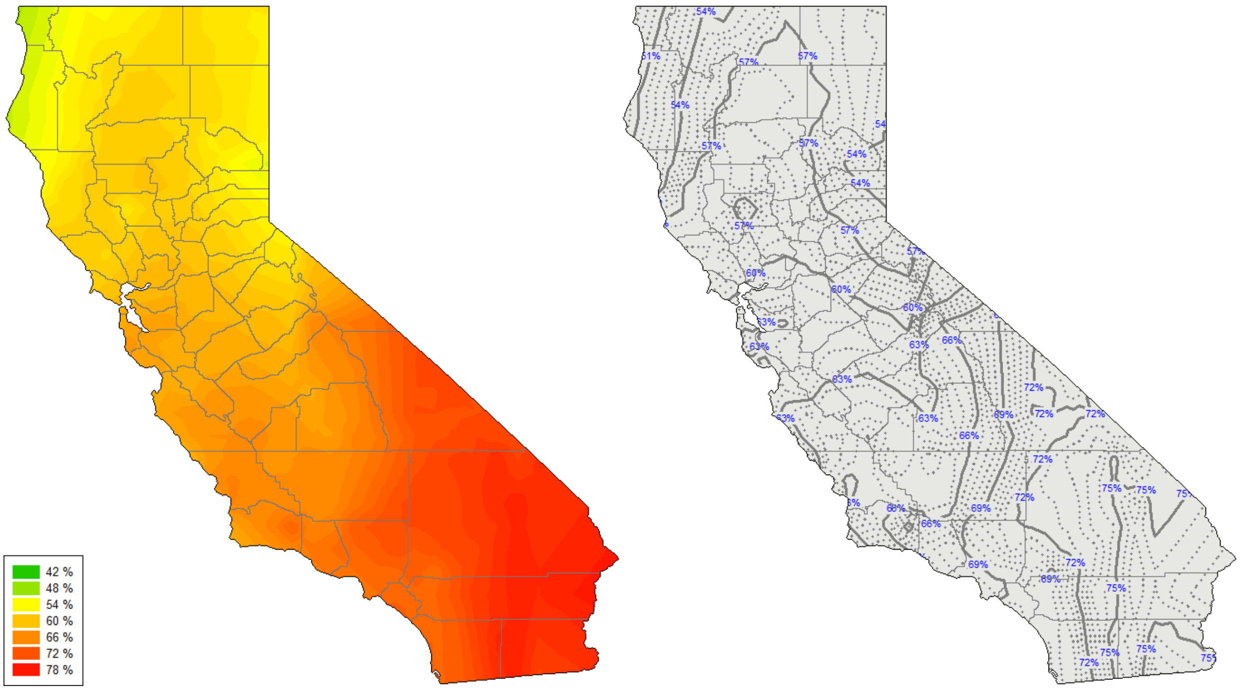


Figure G7. Annual fractional energy savings (%) for G64FPCL



Appendix H: *EGUSA* Auxiliary Electric Water Heaters Contour Plots for Florida

Figure H1. Annual energy consumption in kWh for a standard storage electric water heater

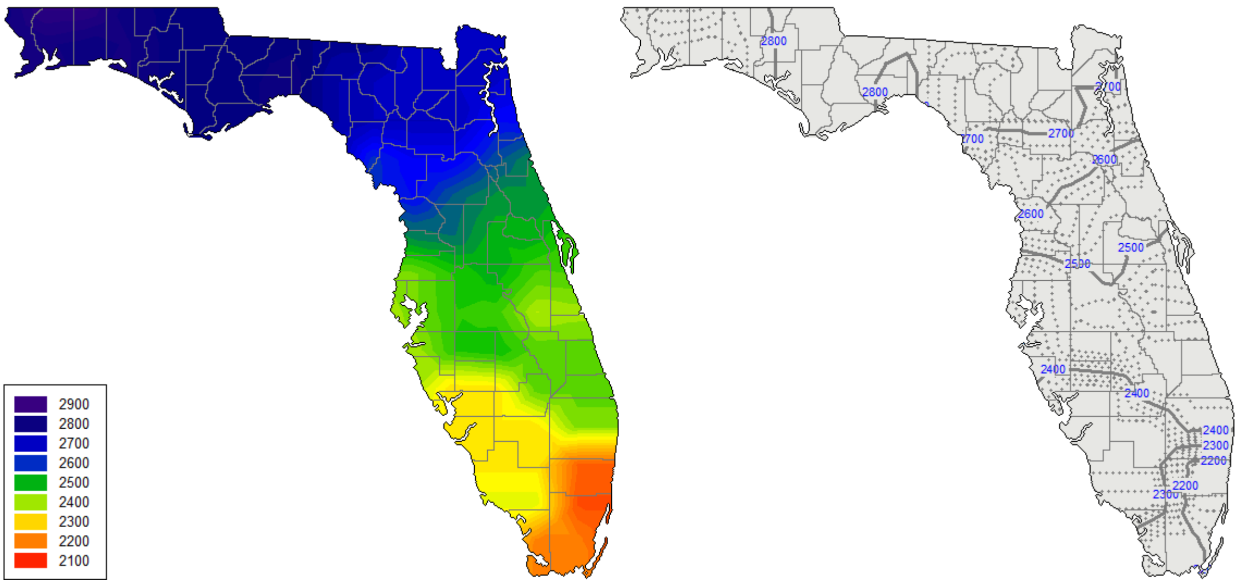


Figure H2. Annual absolute energy savings in kWh for E32ICS

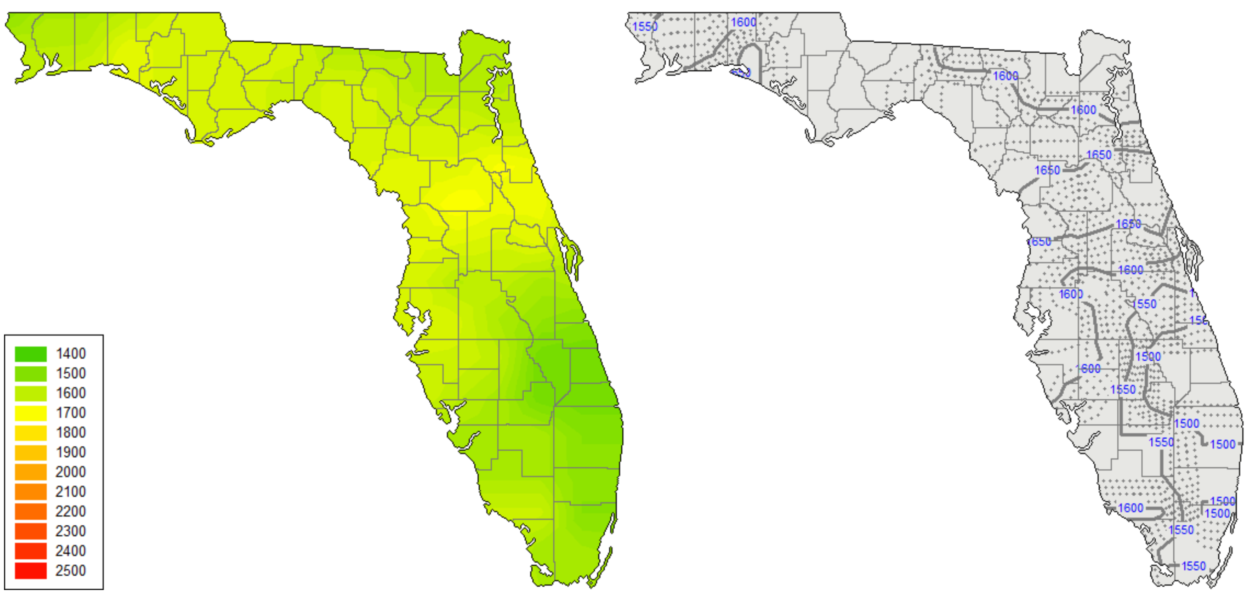


Figure H3. Annual fractional energy savings (%) for E32ICS

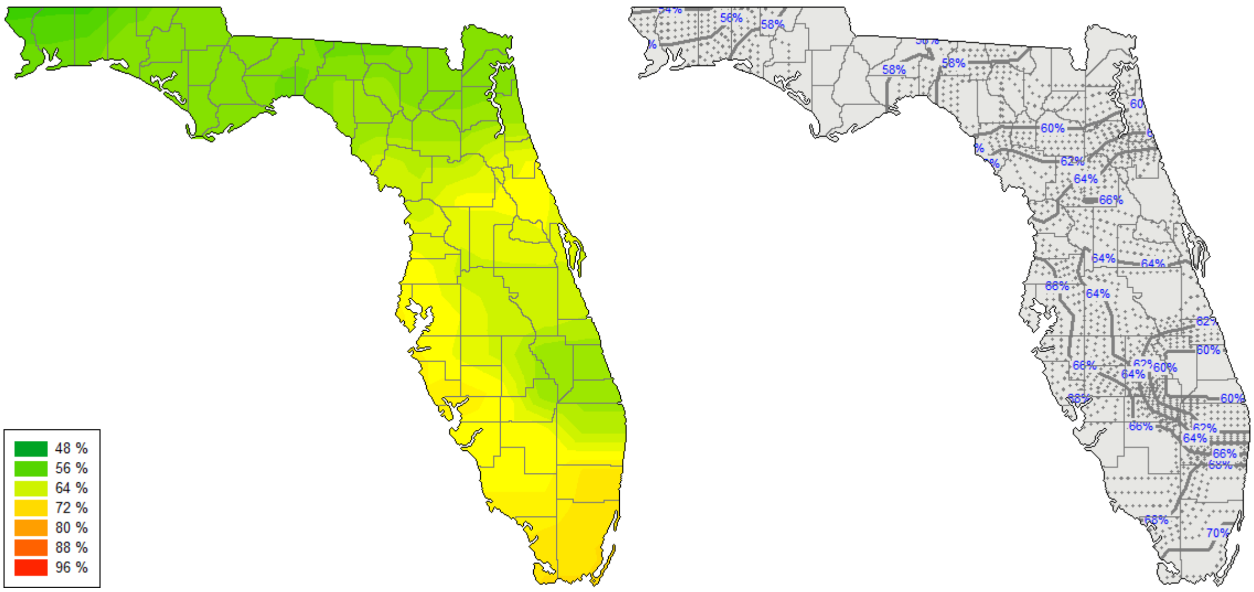


Figure H4. Annual absolute energy savings in kWh for E40FPCL

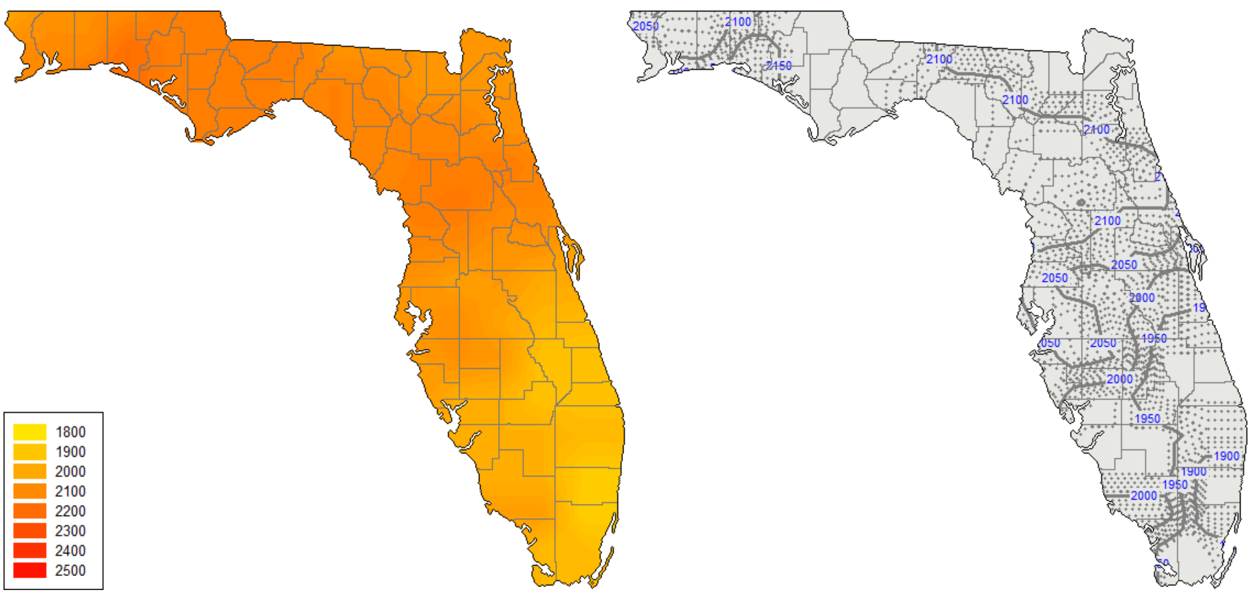


Figure H5. Annual fractional energy savings (%) for E40FPCL

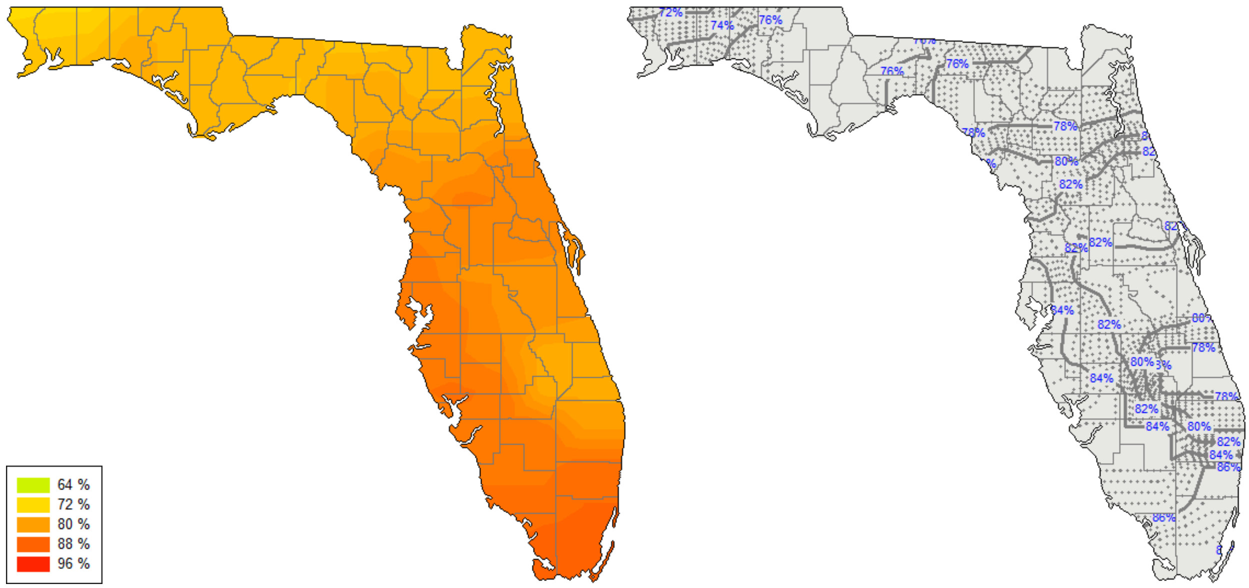


Figure H6. Annual absolute energy savings in kWh for E64FPCL

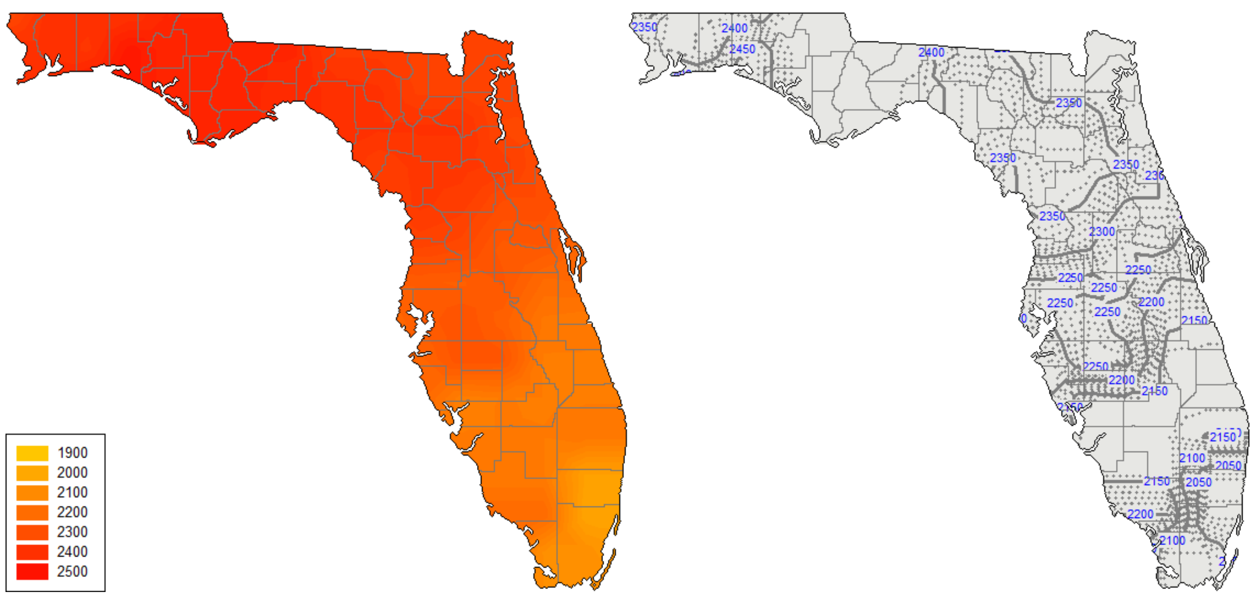
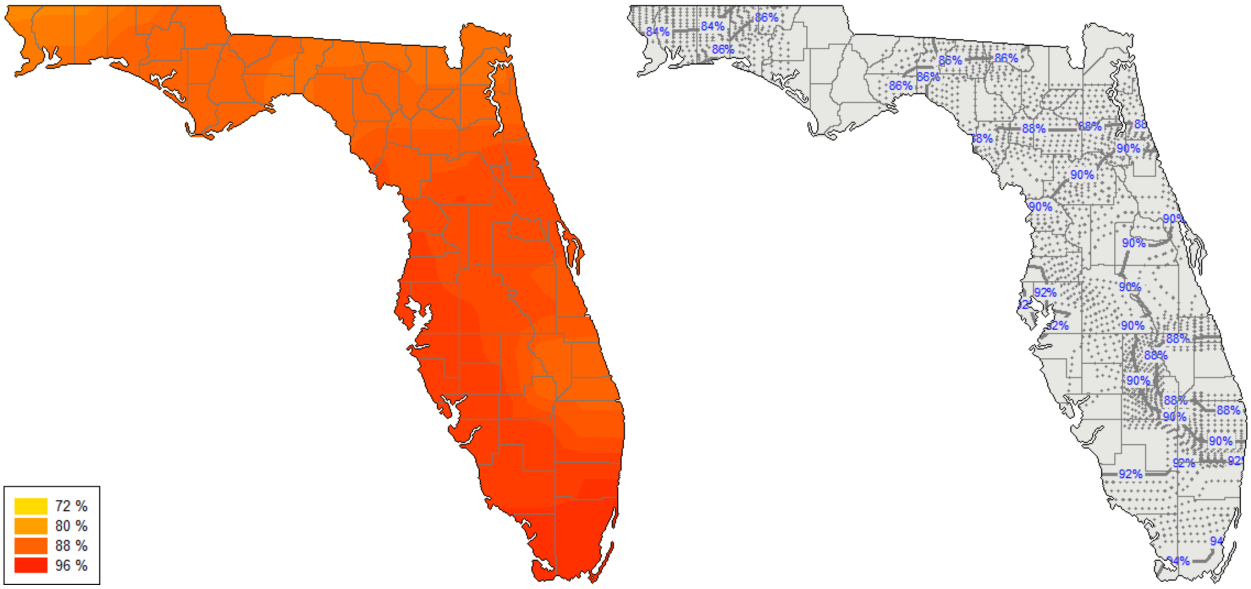


Figure H7. Annual fractional energy savings (%) for E64FPCL



Appendix I: Difference in prediction of absolute energy savings in *BEopt* with respect to *EGUSA* on a city by city basis

Table I1. Electric Systems

		E32ICS		E40FPCL		E64FPCL	
State	**City**	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%
ALABAMA	BIRMINGHAM	141	8.9	55	2.5	44	1.7
	MOBILE	116	7.4	54	2.6	52	2.2
	MONTGOMERY	116	7.0	55	2.5	38	1.5
ARIZONA	FLAGSTAFF	562	32.4	157	5.4	86	2.4
	PHOENIX	155	10.0	33	1.7	55	2.7
	PRESCOTT	235	11.8	169	6.3	77	2.5
	TUCSON	170	9.2	81	3.6	45	1.8
ARKANSAS	FORT SMITH	233	15.1	144	6.8	111	4.4
	LITTLE ROCK	37	2.4	22	1.1	40	1.6
CALIFORNIA	ARCATA	183	12.7	210	10.7	196	7.5
	BAKERSFIELD	143	8.4	59	2.8	51	2.1
	FRESNO	138	8.1	68	3.2	50	2.1
	LONG BEACH	117	6.3	106	4.5	61	2.2
	LOS ANGELES	125	6.6	122	5.1	61	2.2
	SACRAMENTO	172	9.9	79	3.5	54	2.1
	SAN DIEGO	90	4.6	-25	-1.0	-107	-3.7
	SAN FRANCISCO	150	8.3	164	6.9	103	3.6
COLORADO	ALAMOSA	819	49.5	280	9.2	122	3.1
	COLORADO SPRINGS	465	28.4	220	8.5	124	3.8
	EAGLE	623	42.6	278	10.9	170	5.1
	GRAND JUNCTION	406	24.3	152	6.0	73	2.4
	PUEBLO	362	20.0	184	7.0	94	3.0
CONNECTICUT	BRIDGEPORT	360	28.2	194	9.8	167	6.5
	HARTFORD	394	33.3	158	8.0	122	4.8
DELAWARE	WILMINGTON	288	21.0	130	6.2	101	3.9
FLORIDA	DAYTONA BEACH	96	5.8	46	2.2	31	1.3
	JACKSONVILLE	92	5.9	66	3.2	64	2.7
	MIAMI	89	5.9	1	0.1	11	0.5
	TALLAHASSEE	102	6.4	75	3.6	65	2.7
	TAMPA	111	6.8	33	1.6	28	1.3
	WEST PALM BEACH	90	5.7	4	0.2	-4	-0.2
GEORGIA	ATHENS	154	9.6	96	4.4	86	3.4
	ATLANTA	173	10.8	78	3.6	78	3.0
	AUGUSTA	121	7.3	75	3.4	52	2.0
	COLUMBUS	132	8.4	73	3.5	57	2.4
	MACON	118	7.3	58	2.7	52	2.1
	SAVANNAH	107	6.7	72	3.4	70	2.9
IDAHO	BOISE	287	18.6	174	7.8	130	4.9
	POCATELLO	419	27.7	201	8.4	111	3.8
ILLINOIS	CHICAGO	390	32.1	239	12.5	244	10.1
	MOLINE	397	30.6	142	6.6	89	3.3
	PEORIA	373	27.9	151	7.1	95	3.5
	ROCKFORD	463	38.9	187	9.1	132	5.0
	SPRINGFIELD	355	25.9	142	6.6	115	4.3
INDIANA	EVANSVILLE	234	16.1	111	5.3	99	3.9
	FORT WAYNE	412	35.2	191	9.8	142	5.7
	INDIANAPOLIS	367	28.6	160	7.8	109	4.2
	SOUTH BEND	343	28.9	167	8.8	127	5.2
IOWA	DES MOINES	427	31.5	144	6.4	81	2.9
	MASON CITY	500	41.9	207	9.9	140	5.1
	SIOUX CITY	444	33.5	179	8.1	130	4.7
	WATERLOO	446	35.7	197	9.3	142	5.2
KANSAS	DODGE CITY	350	21.2	153	6.2	105	3.5
	GOODLAND	419	25.1	142	5.4	77	2.4

		E32ICS		E40FPCL		E64FPCL	
State	**City**	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%
	TOPEKA	333	23.2	111	5.0	86	3.1
	WICHITA	271	16.9	117	5.0	93	3.4
KENTUCKY	LEXINGTON	279	21.2	131	6.5	102	4.1
	LOUISVILLE	201	16.5	157	8.9	177	7.9
LOUISIANA	BATON ROUGE	101	6.8	49	2.5	47	2.1
	LAKE CHARLES	103	6.7	34	1.7	32	1.4
	NEW ORLEANS	91	6.0	37	1.9	49	2.2
	SHREVEPORT	192	12.7	138	6.8	148	6.3
MAINE	PORTLAND	546	45.8	171	7.9	121	4.3
MARYLAND	BALTIMORE	246	17.4	89	4.2	60	2.3
MASSACHUSETTS	BOSTON	384	30.4	129	6.3	105	4.0
	WORCESTER	506	43.8	132	6.3	89	3.2
MICHIGAN	ALPENA	558	54.7	225	11.6	161	6.2
	DETROIT	345	31.3	198	11.1	176	7.6
	FLINT	412	37.1	196	10.5	156	6.4
	GRAND RAPIDS	382	32.8	207	10.9	160	6.5
	HOUGHTON LAKE	466	46.8	273	15.6	251	10.7
MICHIGAN	LANSING	376	32.3	210	11.1	164	6.6
	MUSKEGON	394	34.2	218	11.6	174	7.2
	SAULT STE. MARIE	598	60.5	240	12.4	186	7.1
	TRAVERSE CITY	446	42.6	227	12.5	186	7.7
MINNESOTA	DULUTH	616	59.4	262	13.1	208	7.6
	INTERNATIONAL FALLS	561	56.5	312	16.9	260	10.2
	MINNEAPOLIS	527	45.6	211	10.1	178	6.6
	ROCHESTER	502	44.4	248	12.4	189	7.2
MISSISSIPPI	JACKSON	283	17.6	63	2.9	49	2.0
	MERIDIAN	134	8.6	111	5.4	110	4.5
MISSOURI	COLUMBIA	323	22.3	122	5.5	74	2.7
	KANSAS CITY	360	25.0	113	5.0	95	3.4
	SPRINGFIELD	283	19.3	145	6.7	122	4.6
	ST. LOUIS	282	20.2	75	3.5	45	1.7
MONTANA	BILLINGS	391	27.7	177	7.9	121	4.3
	CUT BANK	473	35.0	208	9.1	138	4.7
	GLASGOW	482	37.7	242	11.2	178	6.4
	GREAT FALLS	377	27.2	223	10.2	176	6.2
	HELENA	467	35.8	198	9.0	125	4.4
	KALISPELL	398	34.0	238	12.5	186	7.5
	LEWISTON	496	39.5	214	9.8	150	5.3
	MILES CITY	430	30.4	178	7.8	108	3.7
	MISSOULA	332	26.1	217	11.0	153	6.0
NEBRASKA	GRAND ISLAND	470	33.3	173	7.3	108	3.7
	NORFOLK	484	35.5	177	7.7	121	4.2
	NORTH PLATTE	453	30.8	175	7.2	104	3.4
	SCOTTSBLUFF	463	31.2	147	6.0	67	2.2
NEVADA	ELKO	497	31.3	161	6.2	67	2.1
	ELY	699	46.5	166	6.0	70	2.0
	LAS VEGAS	161	9.1	21	0.9	40	1.6
	RENO	315	17.4	81	3.1	31	1.0
	TONOPAH	412	22.5	85	3.1	14	0.4
	WINNEMUCCA	406	24.1	132	5.1	71	2.3
NEW HAMPSHIRE	CONCORD	502	44.1	190	9.3	136	5.1
NEW JERSEY	ATLANTIC CITY	289	20.5	110	5.1	83	3.0
	NEWARK	312	24.2	103	5.1	74	2.9
NEW MEXICO	ALBUQUERQUE	254	12.7	70	2.5	43	1.3
	TUCUMCARI	281	15.2	86	3.3	55	1.8
NEW YORK	ALBANY	425	35.6	150	7.4	105	4.0
	BINGHAMTON	446	41.6	160	8.5	113	4.5
	BUFFALO	394	34.9	180	9.6	132	5.4
	MASSENA	493	45.2	188	9.6	136	5.2
	NEW YORK CITY	245	17.9	113	5.6	96	3.8
	ROCHESTER	362	32.0	181	9.9	145	6.1
	SYRACUSE	393	34.5	169	8.9	138	5.6
NORTH CAROLINA	ASHEVILLE	233	14.9	137	6.0	127	4.5

		E32ICS		E40FPCL		E64FPCL	
State	**City**	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%
	CAPE HATTERAS	124	7.8	58	2.7	55	2.2
	CHARLOTTE	152	9.4	85	3.8	62	2.4
	GREENSBORO	230	15.5	116	5.4	102	3.9
	RALEIGH	168	10.8	108	5.0	98	3.8
	WILMINGTON	64	4.0	64	3.0	113	4.5
NORTH DAKOTA	BISMARCK	487	37.3	317	14.5	361	12.8
	FARGO	544	45.9	278	13.1	300	10.7
	MINOT	587	50.7	420	21.1	366	13.8
OHIO	AKRON	231	20.5	88	4.9	118	5.0
	CLEVELAND	347	33.3	271	16.3	306	14.0
	COLUMBUS	220	17.8	90	4.7	132	5.4
	DAYTON	279	22.9	110	5.6	152	6.1
	MANSFIELD	391	34.6	180	9.6	153	6.2
	TOLEDO	351	28.0	186	9.3	139	5.4
	YOUNGSTOWN	327	29.1	199	11.2	177	7.6
OKLAHOMA	OKLAHOMA CITY	171	11.1	102	4.7	124	4.9
	TULSA	246	16.2	104	4.8	92	3.6
OREGON	ASTORIA	172	15.4	163	10.1	174	8.1
	BURNS	460	31.3	196	8.2	121	4.0
	EUGENE	199	15.4	220	12.2	193	8.6
	MEDFORD	180	11.4	148	6.9	119	4.6
	NORTH BEND	171	11.6	117	5.7	96	3.6
	PENDLETON	209	13.7	133	6.3	108	4.2
	PORTLAND	187	15.3	181	10.6	169	7.9
	REDMOND	299	18.8	193	8.3	125	4.3
	SALEM	198	15.4	179	9.9	156	6.9
PENNSYLVANIA	ALLENTOWN	351	28.4	122	6.1	76	3.0
	BRADFORD	469	44.4	211	11.3	155	6.1
	ERIE	368	33.0	197	11.0	168	7.3
	HARRISBURG	211	16.5	-9	-0.4	-27	-1.0
	PHILADELPHIA	271	19.5	126	6.0	96	3.7
PENNSYLVANIA	PITTSBURGH	345	29.1	167	8.8	131	5.4
	WILKES-BARRE	367	31.6	142	7.4	100	4.0
	WILLIAMSPORT	349	29.9	155	8.2	121	4.9
RHODE ISLAND	PROVIDENCE	362	28.9	132	6.5	111	4.2
SOUTH CAROLINA	CHARLESTON	113	7.0	61	2.9	59	2.4
	COLUMBIA	130	8.2	89	4.2	76	3.1
SOUTH DAKOTA	PIERRE	396	28.3	200	9.0	144	5.1
	RAPID CITY	470	32.2	156	6.4	86	2.8
	SIOUX FALLS	471	36.5	213	9.7	166	5.9
TENNESSEE	CHATTANOOGA	148	9.9	91	4.4	87	3.5
	KNOXVILLE	251	17.7	104	5.0	94	3.7
	MEMPHIS	151	9.8	71	3.4	73	3.0
	NASHVILLE	220	15.0	95	4.5	88	3.5
TEXAS	ABILENE	173	9.8	106	4.6	183	7.2
	AMARILLO	231	12.6	103	4.0	65	2.1
	AUSTIN	103	7.0	47	2.5	68	3.1
	BROWNSVILLE	90	6.3	15	0.8	20	1.0
	CORPUS CHRISTI	90	6.3	18	1.0	17	0.8
	EL PASO	168	8.4	38	1.5	12	0.4
	FORT WORTH	147	9.3	87	4.1	84	3.4
	HOUSTON	95	6.4	43	2.2	56	2.5
	LUBBOCK	201	11.2	115	4.7	99	3.5
	LUFKIN	100	6.4	42	2.1	41	1.7
	MIDLAND	156	8.4	90	3.7	60	2.2
	PORT ARTHUR	93	6.2	23	1.2	26	1.2
	SAN ANGELO	160	9.1	91	3.9	54	2.1
	SAN ANTONIO	103	6.4	28	1.4	27	1.2
	VICTORIA	77	5.1	2	0.1	-3	-0.1
	WACO	119	7.4	11	0.5	16	0.7
	WICHITA FALLS	174	10.4	74	3.3	63	2.4
UTAH	CEDAR CITY	416	23.2	111	4.0	29	0.9
	SALT LAKE CITY	296	19.1	128	5.6	77	2.8

		E32ICS		E40FPCL		E64FPCL	
State	**City**	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%	***BEopt*-EG** (kWh)	%
VERMONT	BURLINGTON	430	38.3	193	10.2	160	6.4
VIRGINIA	LYNCHBURG	242	15.7	102	4.6	73	2.7
	NORFOLK	194	13.1	86	4.1	65	2.6
	RICHMOND	202	13.3	98	4.5	94	3.6
	ROANOKE	251	17.1	102	4.7	81	3.0
	WASHINGTON D.C.	66	4.9	-59	-2.9	-33	-1.3
WASHINGTON	OLYMPIA	219	20.3	222	14.3	214	10.4
	QUILLAYUTE	217	21.2	222	15.1	212	10.6
	SEATTLE	158	13.3	127	7.6	113	5.3
	SPOKANE	390	31.0	292	15.4	298	12.7
	YAKIMA	263	17.9	188	8.9	148	5.7
WEST VIRGINIA	CHARLESTON	250	18.6	128	6.4	109	4.3
	HUNTINGTON	222	16.6	112	5.7	92	3.7
WISCONSIN	EAU CLAIRE	506	43.9	186	9.0	118	4.3
	GREEN BAY	518	46.3	185	9.1	130	4.8
	LA CROSSE	475	39.7	199	9.6	152	5.7
	MILWAUKEE	469	39.6	158	7.7	99	3.7
WYOMING	CASPER	553	38.7	147	5.8	44	1.4
	CHEYENNE	533	36.5	137	5.4	61	1.9
	LANDER	552	35.9	159	6.0	85	2.6

Table I2. Natural Gas Systems

		G32ICS		G40FPCL		G64FPCL	
State	**City**	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%
ALABAMA	BIRMINGHAM	18	32.1	21	24.7	26	24.1
	MOBILE	18	33.3	22	26.8	28	27.5
	MONTGOMERY	18	31.0	22	25.3	27	24.8
ARIZONA	FLAGSTAFF	36	60.0	29	26.6	31	21.1
	PHOENIX	29	50.0	31	36.9	33	34.7
	PRESCOTT	25	35.7	32	30.8	34	25.8
	TUCSON	25	37.3	35	36.8	36	32.4
ARKANSAS	FORT SMITH	21	38.2	28	33.7	31	29.2
	LITTLE ROCK	13	24.1	20	25.3	24	23.8
CALIFORNIA	ARCATA	17	34.0	25	34.2	26	25.2
	BAKERSFIELD	21	33.9	30	34.1	31	29.8
	FRESNO	20	32.3	30	34.5	30	28.8
	LONG BEACH	20	31.3	27	29.0	30	25.6
	LOS ANGELES	21	32.3	26	27.7	30	25.0
	SACRAMENTO	20	32.3	29	31.9	30	27.5
	SAN DIEGO	20	29.0	22	21.6	25	19.7
	SAN FRANCISCO	20	32.3	26	28.6	29	24.2
COLORADO	ALAMOSA	46	80.7	35	31.0	37	24.0
	COLORADO SPRINGS	31	54.4	32	33.3	33	25.4
	EAGLE	35	68.6	33	35.1	33	25.2
	GRAND JUNCTION	30	50.8	32	33.3	32	25.8
	PUEBLO	29	46.0	34	34.0	35	26.9
CONNECTICUT	BRIDGEPORT	24	54.5	25	33.8	27	26.5
	HARTFORD	24	58.5	24	32.9	25	24.8
DELAWARE	WILMINGTON	23	48.9	24	30.8	27	25.7
FLORIDA	DAYTONA BEACH	18	31.0	24	27.9	30	29.1
	JACKSONVILLE	16	29.1	21	25.3	28	27.5
	MIAMI	18	34.0	21	25.9	29	31.2
	TALLAHASSEE	16	28.6	23	27.4	28	26.9
	TAMPA	18	30.5	24	27.6	32	31.7
	WEST PALM BEACH	18	32.1	21	25.0	29	29.6
GEORGIA	ATHENS	18	32.1	23	27.1	29	26.9
	ATLANTA	19	33.9	24	27.9	28	25.7
	AUGUSTA	18	31.0	24	27.6	28	25.5
	COLUMBUS	18	32.7	24	29.3	29	28.2
	MACON	17	29.8	24	28.2	28	26.4
	SAVANNAH	17	29.8	23	27.1	29	27.9
IDAHO	BOISE	23	42.6	28	32.6	30	27.3
	POCATELLO	27	50.9	28	31.1	29	24.2
ILLINOIS	CHICAGO	24	55.8	25	34.2	30	30.9
	MOLINE	25	55.6	24	30.0	26	24.1
	PEORIA	24	51.1	24	30.0	26	24.1
	ROCKFORD	27	65.9	26	34.7	27	26.0
	SPRINGFIELD	24	50.0	24	29.3	27	24.8
INDIANA	EVANSVILLE	20	39.2	24	30.0	27	25.7
	FORT WAYNE	24	58.5	24	32.9	27	27.3
	INDIANAPOLIS	24	53.3	25	32.5	26	25.0
	SOUTH BEND	22	53.7	24	33.8	26	26.8
IOWA	DES MOINES	27	57.4	25	29.8	27	24.1
	MASON CITY	29	70.7	27	35.1	27	25.0
	SIOUX CITY	28	60.9	27	32.9	29	26.1
	WATERLOO	27	62.8	26	33.3	29	27.1
KANSAS	DODGE CITY	28	48.3	30	31.6	33	26.8
	GOODLAND	30	51.7	29	29.3	31	23.8
	TOPEKA	25	50.0	25	29.4	28	25.2
	WICHITA	23	40.4	27	30.0	30	26.1
KENTUCKY	LEXINGTON	21	45.7	23	30.3	26	25.5
	LOUISVILLE	16	37.2	22	32.8	26	28.9
LOUISIANA	BATON ROUGE	15	28.3	21	26.9	26	26.8

		G32ICS		G40FPCL		G64FPCL	
State	**City**	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%
	LAKE CHARLES	17	31.5	22	27.2	27	27.0
	NEW ORLEANS	17	32.1	21	26.3	27	27.6
	SHREVEPORT	19	34.5	27	33.3	33	33.0
MAINE	PORTLAND	31	75.6	25	31.6	26	23.4
MARYLAND	BALTIMORE	20	40.8	21	26.3	24	22.6
MASSACHUSETTS	BOSTON	25	56.8	23	29.9	25	23.8
	WORCESTER	29	72.5	23	29.9	23	21.1
MICHIGAN	ALPENA	29	80.6	26	36.6	26	25.7
	DETROIT	22	57.9	24	36.4	27	29.7
	FLINT	23	59.0	24	34.8	25	25.8
	GRAND RAPIDS	23	57.5	25	35.7	27	28.1
	HOUGHTON LAKE	26	76.5	27	42.2	28	30.8
MICHIGAN	LANSING	24	60.0	26	37.1	28	28.9
	MUSKEGON	23	57.5	25	36.2	27	28.1
	SAULT STE. MARIE	31	91.2	27	38.6	27	26.7
	TRAVERSE CITY	25	69.4	26	39.4	26	27.7
MINNESOTA	DULUTH	31	86.1	28	38.4	27	25.7
	INTERNATIONAL FALLS	29	85.3	30	44.8	30	30.9
	MINNEAPOLIS	29	72.5	26	33.8	28	26.2
	ROCHESTER	28	71.8	27	37.0	29	28.2
MISSISSIPPI	JACKSON	18	31.6	23	27.1	28	26.4
	MERIDIAN	18	33.3	24	29.6	29	28.2
MISSOURI	COLUMBIA	24	47.1	24	28.2	28	25.2
	KANSAS CITY	25	49.0	26	30.2	28	24.6
	SPRINGFIELD	22	42.3	25	30.1	29	26.9
	ST. LOUIS	22	44.9	22	27.2	24	22.4
MONTANA	BILLINGS	26	53.1	27	32.5	29	25.9
	CUT BANK	28	59.6	27	32.1	27	23.1
	GLASGOW	28	63.6	29	36.7	30	27.5
	GREAT FALLS	25	52.1	28	34.6	30	27.0
	HELENA	28	62.2	27	33.3	28	25.0
	KALISPELL	23	56.1	26	36.6	27	27.6
	LEWISTON	29	67.4	27	33.8	28	25.0
	MILES CITY	27	55.1	27	31.8	29	25.4
	MISSOULA	22	50.0	26	35.6	26	25.7
NEBRASKA	GRAND ISLAND	28	56.0	27	30.3	29	24.4
	NORFOLK	30	63.8	28	32.6	29	25.0
	NORTH PLATTE	28	53.8	28	30.8	29	23.6
	SCOTTSBLUFF	30	57.7	28	30.4	29	23.6
NEVADA	ELKO	32	58.2	30	30.9	31	24.2
	ELY	40	76.9	30	29.1	30	21.4
	LAS VEGAS	27	41.5	30	31.6	33	30.0
	RENO	26	40.6	29	28.4	29	22.3
	TONOPAH	31	48.4	30	28.0	30	22.1
	WINNEMUCCA	28	46.7	29	29.3	29	22.7
NEW HAMPSHIRE	CONCORD	28	70.0	25	33.3	26	24.8
NEW JERSEY	ATLANTIC CITY	22	44.9	22	26.8	25	22.7
	NEWARK	22	48.9	21	27.3	23	22.3
NEW MEXICO	ALBUQUERQUE	26	36.6	29	26.6	31	22.8
	TUCUMCARI	26	40.0	27	26.2	30	23.1
NEW YORK	ALBANY	25	61.0	23	30.7	24	23.1
	BINGHAMTON	25	67.6	23	33.3	22	22.4
	BUFFALO	24	61.5	24	34.8	25	26.0
	MASSENA	27	71.1	24	33.3	24	23.5
	NEW YORK CITY	19	39.6	22	28.6	24	23.3
	ROCHESTER	23	59.0	24	35.3	25	26.6
	SYRACUSE	23	57.5	23	32.9	25	25.8
NORTH CAROLINA	ASHEVILLE	20	36.4	24	27.9	27	23.3
	CAPE HATTERAS	17	30.4	21	25.0	26	24.5
	CHARLOTTE	18	31.6	23	26.7	28	25.2
	GREENSBORO	20	38.5	24	29.3	27	25.0
	RALEIGH	19	35.2	23	27.7	28	25.9

		G32ICS		G40FPCL		G64FPCL	
State	**City**	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%
	WILMINGTON	13	23.2	17	20.2	25	23.6
NORTH DAKOTA	BISMARCK	27	58.7	30	37.0	36	32.4
	FARGO	30	73.2	29	37.2	33	30.3
	MINOT	31	77.5	34	46.6	37	35.9
OHIO	AKRON	16	41.0	19	28.8	20	21.7
	CLEVELAND	21	58.3	26	41.9	30	34.9
	COLUMBUS	17	39.5	19	26.4	22	22.4
	DAYTON	19	44.2	20	27.4	23	23.0
	MANSFIELD	24	61.5	24	34.8	26	27.1
	TOLEDO	22	50.0	25	33.8	27	26.5
	YOUNGSTOWN	20	51.3	24	36.9	25	27.5
OKLAHOMA	OKLAHOMA CITY	17	30.9	22	25.9	29	26.9
	TULSA	21	38.2	25	29.1	29	26.6
OREGON	ASTORIA	14	35.9	20	33.3	21	24.7
	BURNS	28	53.8	28	31.1	29	24.0
	EUGENE	17	37.8	26	38.8	28	30.8
	MEDFORD	19	34.5	26	31.3	29	27.4
	NORTH BEND	16	31.4	20	25.6	22	20.8
	PENDLETON	19	35.8	24	29.6	27	26.0
	PORTLAND	15	34.9	23	35.9	24	27.6
	REDMOND	24	43.6	28	31.8	30	25.6
	SALEM	16	35.6	23	33.3	25	27.2
PENNSYLVANIA	ALLENTOWN	23	53.5	22	29.3	24	23.5
	BRADFORD	26	72.2	25	37.3	25	25.8
	ERIE	22	56.4	25	37.9	25	27.2
	HARRISBURG	16	35.6	16	21.1	16	15.4
	PHILADELPHIA	22	45.8	23	29.1	26	24.8
PENNSYLVANIA	PITTSBURGH	22	53.7	23	32.4	25	25.8
	WILKES-BARRE	22	53.7	22	31.0	23	23.5
	WILLIAMSPORT	21	51.2	22	31.0	23	23.5
RHODE ISLAND	PROVIDENCE	24	55.8	23	30.7	24	23.1
SOUTH CAROLINA	CHARLESTON	17	29.8	23	27.1	28	26.4
	COLUMBIA	18	32.7	24	28.9	29	27.6
SOUTH DAKOTA	PIERRE	27	56.3	28	33.7	30	26.8
	RAPID CITY	31	62.0	28	31.1	29	24.0
	SIOUX FALLS	28	62.2	27	33.3	29	26.1
TENNESSEE	CHATTANOOGA	17	32.1	22	27.2	26	24.8
	KNOXVILLE	20	40.0	23	28.8	27	25.7
	MEMPHIS	19	35.2	24	29.3	28	27.2
	NASHVILLE	21	41.2	23	28.4	28	26.9
TEXAS	ABILENE	21	32.8	26	27.1	34	30.1
	AMARILLO	23	35.9	28	28.0	31	24.4
	AUSTIN	17	32.7	24	31.2	27	28.4
	BROWNSVILLE	15	29.4	21	27.6	28	31.1
	CORPUS CHRISTI	16	31.4	22	28.9	26	28.0
	EL PASO	25	35.2	31	29.8	33	26.8
	FORT WORTH	18	32.1	25	29.8	31	29.5
	HOUSTON	16	30.8	22	28.2	26	26.8
	LUBBOCK	23	36.5	29	29.9	33	27.3
	LUFKIN	16	28.6	23	28.0	27	26.5
	MIDLAND	21	31.8	29	29.6	32	26.9
	PORT ARTHUR	16	30.2	21	26.6	26	26.8
	SAN ANGELO	21	33.3	28	29.8	32	28.1
	SAN ANTONIO	18	31.0	24	28.2	29	28.4
	VICTORIA	16	30.2	20	25.0	23	23.5
	WACO	19	33.3	24	27.9	27	25.7
	WICHITA FALLS	20	33.3	26	28.9	30	27.3
UTAH	CEDAR CITY	30	47.6	29	27.4	30	21.9
	SALT LAKE CITY	23	41.8	28	32.2	30	26.8
VERMONT	BURLINGTON	25	65.8	25	36.2	26	26.8
VIRGINIA	LYNCHBURG	22	41.5	24	28.2	28	25.2
	NORFOLK	19	36.5	22	27.2	26	24.5

		G32ICS		G40FPCL		G64FPCL	
State	**City**	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%	***BEopt*-EG** (Therms)	%
	RICHMOND	20	37.7	23	27.7	26	23.9
	ROANOKE	21	41.2	23	27.7	26	23.6
	WASHINGTON D.C.	12	25.0	14	18.2	17	16.8
WASHINGTON	OLYMPIA	16	43.2	23	39.7	24	29.6
	QUILLAYUTE	15	42.9	23	42.6	23	29.5
	SEATTLE	14	34.1	20	31.7	21	24.4
	SPOKANE	24	54.5	30	42.3	34	36.2
	YAKIMA	21	41.2	27	33.8	29	27.4
WEST VIRGINIA	CHARLESTON	19	40.4	22	28.9	24	23.5
	HUNTINGTON	19	41.3	22	29.7	24	24.0
WISCONSIN	EAU CLAIRE	28	70.0	25	32.9	25	23.4
	GREEN BAY	28	71.8	25	33.3	25	23.8
	LA CROSSE	27	64.3	26	33.8	27	25.5
	MILWAUKEE	27	65.9	23	30.3	24	22.6
WYOMING	CASPER	33	67.3	27	29.0	28	22.2
	CHEYENNE	33	66.0	26	27.7	27	20.8
	LANDER	34	64.2	28	28.3	30	22.6